Transactions of American Society for Steel Treating

Published Monthly
Cleveland, April, 1921
Ten Dollars a Year
Vol. I
Application for entry as second class matter at the post-office at Cleveland, Ohio, pending
No. 7

SPECIAL FEATURES

Table of Contents, Page 33

4600 Prospect Avenue

TRANSACTIONS
of the
American Society for Steel Treating

Vol. 1 **Cleveland, April, 1921** **No. 7**

SELLING YOUR PRODUCT ON MERIT

Manufacturers more and more are realizing the importance of selling their goods on its merits or service performance. In these days of high competition and assortment of goods on the market, the average buyer demands complete information as to how the goods was made and how it was tested to show its ability to withstand the service he wishes to make of it. As a result, methods of manufacturing have been included in the selling points of salesmen.

Particularly is this true in the automotive field where motor car and truck builders have been quick to realize that proper heat treatment of car parts is of vital importance. Through the aid of metallurgical laboratories, manufacturers have passed on to its customers through its sales engineers, the proper hardening of gears to prevent breaking, the relieving of distortion and strain, annealing of parts to prevent warping, final refinement to give strength for the demands of service and many other details of manufacture.

Upon this information depends whether or not the buyer can operate a truck with profit. If manufacture has been slighted, or quality has been passed over for quantity, the cost of repairs will absorb profit of operation. The producer must and does appreciate this critical demand of the consumer and is continually perfecting his product to meet the demands for service.

METALLURGY CONTINUES IN ITS PROGRESS

At the present day with its high development of scientific processes and manufacturing methods, a belief too often exists that the future can not hold in store advances comparable with those of the past. Since man first learned to work with his hands in the early ages, he has continued in his advance through the centuries, devising new tools and new methods to simplify his struggle for existence. To be sure many of his discoveries came about by accident while he was engaged in his search for knowledge but each accomplishment was used as a means for further gain. This characteristic in man has shown itself in every generation and will continue to exist so long as civilization maintains its pace. The world will always expect to see this continuous advancement.

Without doubt the recent development of science has seemed somewhat obscure as a result of the attempt to invent methods for quantity production to meet the ever increasing demand for manufactured articles. Remarkable strides in this respect have been made during the past few

years, the great World War greatly accentuating this advance. Nevertheless, scientific discoveries in the modern arts continued to be made throughout this period.

A brief review of the progress of metallurgy, one of the earliest of arts, shows what progress has been made in the past to bring it to its present day status. But after all, man's experience, with this art and his lack of knowledge emphasize the great development which must come in the future before metallurgy may be classed as a finished science. Dr. Joseph W. Richards, in an article appearing elsewhere in this issue of TRANSACTIONS, points out in detail important development which must be made. Chief among the information needed are specific heats of all kinds of iron and steel, latent heat of fusion for steel, latent heat of vaporization of iron and steel, thermochemistry of metals, heat emissivity, electrical conductivity, and many other properties. Some of these problems already are under investigation by scientists and engineers and their results will at some later date be added to the present knowledge of iron and steel. Each problem solved marks the progress of metallurgy, this progress continuing as time goes on.

PHILADELPHIA CHAPTER HOLDS BIGGEST MEETING SINCE ITS ORGANIZATION

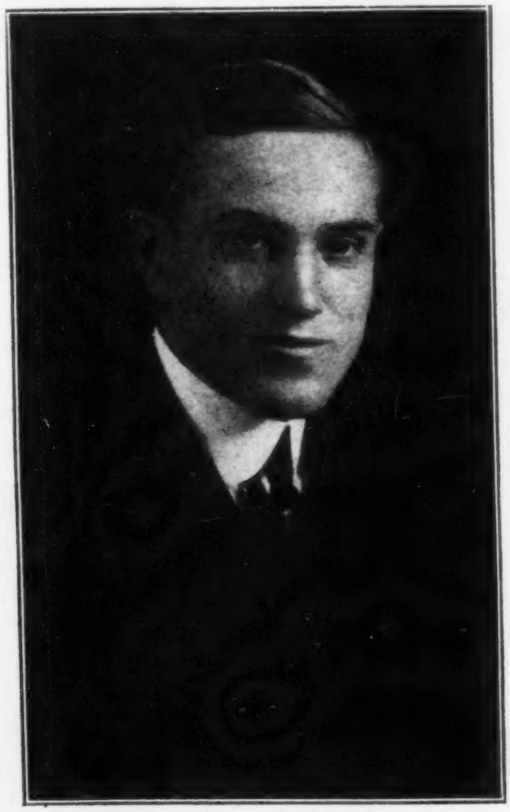
The largest meeting which the Philadelphia Chapter has had since its organization was held on Wednesday evening, Feb. 16, at the Engineers' Club, 1317 Spruce street. Members of the Chapter and their guests took dinner at the club at 6:30, the technical meeting following at 8:15.

Upon this occasion, the Chapter not only entertained and was addressed by Lt. Col. A. E. White, the national president of the Society,

JOHN J. CROWE
Chairman of the Philadelphia Chapter

H. C. KNERR
Chairman, Philadelphia Membership Committee

ARTHUR W. F. GREEN
Vice Chairman of the Philadelphia Chapter



ARTHUR L. COLLINS
Secretary-Treasurer, Philadelphia Chapter

who was making visits to a number of eastern chapters, but was fortunate in having as guests a number of prominent men, among whom were Dr. George K. Burgess, chief of the metallurgical division, Bureau of Standards, Washington; Dr. Joseph W. Richards, professor of metallurgy, Lehigh university, South Bethlehem, Pa.; Morris E. Leeds, president of Leeds & Northrup Co., Philadelphia; and Richard Spillane, business editor, *Public Ledger,* Philadelphia. Dr. John A. Mathews, president of the Crucible Steel Co. of America, Pittsburgh, had also planned to be present but being detained in Pittsburgh at the last moment, wired his regrets and sent a greeting to the chapter.

Each of the guests presented an address which will be found in detail on the following pages. President White, in a brief but highly interesting talk reviewed the growth of the Society and its activities, concluding with an optimism for the future expansion which time would bring. Following the presentation of the formal program, the meeting adjourned for a buffet luncheon, during which a round table discussion of the various papers was held.

An extensive and intensive membership campaign has been conducted by the Chapter recently with gratifying results. H. C. Knerr, metallurgist, Naval Aircraft Factory, United States Navy Yard, Philadelphia, as chairman of the membership committee, has been directing a well planned drive to round out the chapter roll. The membership now is well on its way toward the 300 mark. In the May issue of TRANSACTIONS, Mr. Knerr will report his methods and their success, with a view to assisting other chapters of the Society to swell the membership.

Officers of the Philadelphia Chapter are: John J. Crowe, chairman, metallurgist hull division, Philadelphia Navy Yard; Arthur W. F. Green, vice chairman, chief of laboratory, John Illingsworth Steel Co.; and Arthur L. Collins, secretary-treasurer, metallurgist, Ace Motor Corp.

NATIONAL PRESIDENT GREETS PHILADELPHIA CHAPTER

By Lt. Col. A. E. White*

We are to be congratulated tonight for as I looked over the table I found quite a number of men here whom I met in New York this morning at a meeting of American Mining and Metallurgical Engineers, and note these same men are so deeply interested in this Society and this particular

LT. COL. A. E. WHITE
National President of the Society

meeting that they broke away from their New York engagements and came down to be with us at this particular time.

I never quite realized before that the lot of the average actor and actress was altogether in many respects undesirable. I always thought that those one-night stops which they had when they traveled from city to city must be a joy and a pleasure; but I feel now as though possibly I can sympathize with them somewhat because it has been since a week Friday that I left Ann Arbor, and I don't think I have spent 24 hours in the same place since I left there. And although it has given me great pleasure to be with the different chapters, it has been rather hard to be always running in at 11, 12 or 1 o'clock and getting into another town the next day. I told the first chapters I visited that I regretted very much indeed that I was unable to give them a perspective of what was going on in the various

*Director department of engineering research, University of Michigan, Ann Arbor, Mich., and national president, American Society for Steel Treating.

chapters in the country. It has been my good fortune to visit chapters in Detroit, Cleveland, and Buffalo. I visited chapters in Chicago last spring, and on this trip I am visiting a number of chapters in the East. I felt I was getting more out of the visits than the chapters were getting out of me. I think that is absolutely true. Again I regret as I visit Philadelphia at this time that it was not possible for me to have visited it earlier and to have carried back to the chapters that I have visited the inspiration which I am receiving here tonight. I think I can say without any undue embarrassment to any of our other chapters that I have visited, that if this meeting is a sample of the meetings you have monthly—and reports that we have from Philadelphia indicate that it is—you have without any question the leading chapter of the American Society for Steel Treating.

A week ago Monday night, when I was in Boston, they told me that they were conservative in Boston, and that they didn't want to go too fast because they might spoil that type which they seemed to be proud of. I talked a little frankly to them because I was born 30 miles from Boston; and I can tell this story because it hits me. A man living in Pittsburgh spoke to one living in Boston, and the Bostonian said, "Where do you live?" The Pittsburgher answered, "In Pittsburgh." The Bostonian said, "And where is Pittsburgh?" The Pittsburgher answered, "Anyone who lives 30 miles outside of Boston can answer that question."

I told them at the Boston meeting that I understood Philadelphia was conservative also, but I was also able to tell them that the American Society for Steel Treating in Philadelphia was setting an example for the other chapters of the Society, which was of a most magnificent type.

I have been impressed, however, as I have visited the various chapters, with the magnitude of our organization. When you stop to realize that one night in each month in the year, with the exception of July and August, there is a gathering of this particular type having, I am sorry to say, only about one-half to three-fourths of the number you have here, but at least a gathering on an average of 100 men, meeting for the purpose of discussing the things we are all assembled here to discuss, it seems as though we have something that is worth while. As I attended a meeting in New York this morning relative to rock drill steel and realized the size and immensity of that particular small piece of investigation and realized also that we might carry this investigation to numerous other lines, I feel that we need have no fear of our particular society's running out of material for topics of discussion.

I must not speak too long for you have three or four very able speakers here tonight, and I note that they have very interesting messages to bring to you. I presume I can use the same plan in speaking to you as young ladies do in dressing—they attempt to get enough to cover the subject, and yet they try to make it short enough to be interesting.

Just a few words with regard to what is taking place in a very few of our chapter meetings. You have all received the January issue of TRANSACTIONS. Various data notes have been introduced, and I believe that the character of these notes, as time goes on, will improve. I think Chicago has done exceptionally well in one case. They have established an educational program with night school classes in Armour Institute and in Lewis Institute, and these classes are graduated. The instructional work is done through co-operation with the American Society for Steel Treating and the various

officers and members of that society. In some places round table talks have been most interesting. I understand you had one here the other night, or at least a discussion of one.

The Hartford Chapter I find to be in a particularly healthful condition, and probably one reason they get along so well is because at the very beginning of the year they arranged a definite program for each meeting—it is definitely known what subject is to be talked on and the date for the meeting is definitely set. They have a chapter of over a hundred, and with Hartford being not a very large city, that speaks very well for it. I was given to understand while there that the meetings in Providence might probably be sparsely attended. Of course, there is more or less contention between Hartford and Providence as two of our large machine companies are respectively located in these cities. To my surprise there were 100 to 125 at the Providence meeting on Monday night. There were 100 at the Bridgeport meeting, and over 100 at the Boston meeting; the other places had less. The New Haven Chapter I anticipate will have an increased life now because of certain changes which have taken place. Springfield had an attendance of about 50, in spite of a New England blizzard which started in about 3 o'clock in the afternoon with the prospect of tying up the city at 11 o'clock at night. An attendance of 50 was therefore considered exceptionally good.

It is certain now that the coming convention in 1921 will be held in Indianapolis. I received word that the National Secretary and National Treasurer were leaving Sunday for Indianapolis to complete final arrangements. It was rather desired to hold the convention in Detroit, but the conditions which prevented the meeting in Detroit were the lack of proper hotel facilities and proper convention hall. Cincinnati has made a most excellent bid for the convention, offering special inducements, which made the choice rather difficult.

Our society has grown tremendously. There is no question but that the Philadelphia Chapter has grown tremendously; in fact, I have been given to understand that the Philadelphia Chapter has increased something like 300 per cent since last September. That represents tremendous growth, and the credit rests entirely with your officers, committee, and yourselves for having put this thing across in this way. The National Secretary reported to the postal authorities that we had 2959 members in the Society at the present time—nearly 3000 members. He also told me that our treasury was in a very fair condition for a technical and educational society, namely, $2800.00 in the treasury with only $600.00 owed, leaving a free balance of $2200.00. It is not possible to do very much with that sum; but it means that you belong to a society that is absolutely free from debt and is able to discount its bills, and that there will be absolutely no necessity for raising the dues or asking for special subscriptions from any of you. That I think is an excellent state of affairs to present at this particular time.

I don't know that I have much more to say. I am afraid that if I say much more the skirts will begin to lengthen and the subject will be inappropriately clothed. I extend to you the greetings of the national office. I want you to feel that the national officers are your servants, honored to do your bidding, that we want to make the Society the Society you want it to be. If we can be instruments to put those things into effect that you want put into effect, we want you to realize that we stand ready to do your bidding in every respect.

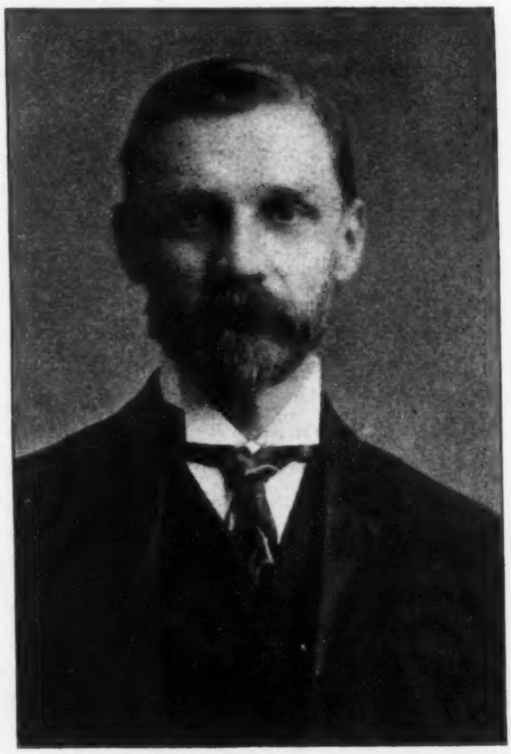
METALLURGICAL PROGRESS OR PROGRESS IN STEEL TREATING

By Dr. Joseph W. Richards*

(A Paper Presented Before the Philadelphia Chapter)

In this article I do not purpose to tell you any of the schemes of the ancients or of the moderns for the treatment of steel. I want to take this opportunity to discuss the subject of metallurgical progress—progress in steel treating, if you like.

The ancients tried out things by rule of thumb, hit or miss. Once in a long while they hit upon something new that worked, and they then made



DR. JOSEPH W. RICHARDS
Professor of Metallurgy, Lehigh University

some progress. At the present time we work intelligently. Our friends the instrument makers give us instruments for control, which tell, for instance, the exact temperatures instead of our having to guess them with the eye. We have now a great deal more information handed down in books, and know more of physical and chemical principles, so that our experimenting is much more intelligent, and we are considerably ahead in that line of anything which the ancients could do.

To go one step farther, however, let me explain the way in which still more fundamental work can be done toward making progress in steel treating. It is my opinion that the first requisite to make progress in any particular operation is to know "Why is works?" and "How it works?"—"Why" and "How." When we attempt to find out "Why" and "How," we get back of experiments, of works experience, back down to the foundation principles

*Professor of metallurgy, Lehigh University, S. Bethlehem, Pa.

which seem very far away from that in which we are ordinarily interested. These foundations of the "Why" and the "How" are in most cases the detailed physical and chemical properties of the materials we are working with, and a deep understanding of the physical and chemical operations to which we are subjecting them. We have to go away down into the cellar for the fundamentals of the subject.

Following are some illustrations of this. For instance, in my book on *Metallurgical Calculations,* there is a chapter on the thermophysics of the elements, their temperature relations as regards their change of state. Let us take these up with regard to iron for instance. First of all there is its specific heat, which means the amount of heat required to raise the temperature of a certain quantity a certain number of degrees. If you look in the books on specific heat of iron you will find some good information about it, but this information is limited to pure iron and one or two samples of steel. What we ought to have is the specific heats of all of the various kinds of iron or steel, the standard qualities which we are using. Now, why do we want to know these? What advantage is there in knowing how much heat is required to bring a certain weight of iron or steel up to a certain temperature? Our information in this line is very fragmentary; a liberal statement would be one-tenth of what we ought to know.

You have a furnace to heat 100 pounds of iron to 800 degrees in order to quench it. You burn gas and the gas bill is sometimes pretty high. How efficient is that furnace? Do you know? You put the iron in, burn the gas, get the result, you have to foot the bill. If you compared the caloric power of the gas with the amount of heat you put into the iron, you would find it possibly about 20 per cent, in other words, your furnace is 20 per cent efficient. When you know that, your first impulse is to get busy and try to improve it. You have an 80 per cent margin to work on. There is an immense incentive to make an improvement when you know what the maximum possible is, and know how little you have been getting. If an electric furnace it put on to that same job of heating up a certain amount of steel to a certain temperature, you calculate the heat value of the electric current used and find that the furnace is 40 or 50 per cent efficient. That is pretty good, and yet you might be dissatisfied with that. Could it be improved upon? If you look at a number of these furnaces you will find that most of them are painted a nice neat black. You then recall from your physics lessons in high school days that black is the best color for radiating heat. Over 50 per cent of the heat has been radiated. "Guess we can save some of that; we'll paint it white," you say.

This reminds me of a personal experience which will illustrate this point. Last winter I bought a new house and moved into it. It had hot water heating. All the hot water pipes in the cellar were painted black and the radiators upstairs were painted white. I got a painter and gave him some dead black paint and some aluminum bronze paint. I had him paint every pipe in the cellar white and every radiator upstairs black. The steel business could apply some of these principles with economy.

Suppose you were melting steel. You might be curious to know how much heat it requires to melt steel. You know it takes a lot of coal, gas, or electricity; but how much heat is required in melting steel? Where could you go for that information? The only place would be to some book of tables which contains determinations made in physical or chemical laboratories. You would look for the latent heat of fusion for steel. How-

ever, it does not exist anywhere; it has not been measured. I made a guess at the latent heat of fusion of pure iron—66 calories per kilogram and probably this is within 10 per cent or 6 calories of the correct value. We don't know how to calculate the latent heat of steel with different percentages of carbon in it. An experimental study ought to be made by someone on the latent heat of fusion for different kinds of steel; we ought to have something more than the latent heat of pure iron, and that only a guess. With the help of the Bureau of Standards, college laboratories, and private industrial laboratories we might get some of these figures.

The Bureau of Standards published last year considerable data on the physical and chemical properties of copper. This was very complete. I am very much interested to know how the collection of data on iron is coming. They will collect all information found anywhere in print, and give it to us. I am sure they won't have much information on the latent heat of fusion of steel but still I believe that is to come.

When you bring steel up to the melting point you have to supply a good many calories in that temperature, and you supply them at an efficiency of about 10 per cent of the heat value of the gas you are using. Electricity however, has this advantage over gas heating that the electric current is just as efficient at 1500 degrees centigrade as it is at 200 degrees centigrade. Its efficiency of conversion into heat is practically the same at high temperatures as at low. You will have to make a detailed study of each furnace to find what its efficiency is; next you will study how it can be improved; then you will have the fundamental facts on which almost certain progress can be based.

Recently I read a paper on arc welding of iron, and it was very interesting. The author discussed where the electrical energy went to, and what per cent was used in melting the iron. He used the guess I had made on the heat of fusion of iron, and found that 40 per cent was used in the operation of melting the iron. He said some of the iron vaporized. How much electrical energy was used in vaporizing the iron?

We know a great deal about the heat of vaporization of water. Books are full of that, but what is the latent heat of vaporization of iron? That is another guess I made in *"Metallurgical Calculations."*. I though it was important to know, so I made a long-shot guess at it. It may be 20 per cent incorrect in value, but something near the truth is better than no idea at all. He figured that 10 per cent of the electric energy was absorbed in vaporizing the iron.

In regard to the latent heat of vaporization of metals, this value has been determined for only two, so far as I know, out of a possible 30 or 40. Here is a field that needs a great deal of experimental work, if we can only get somebody to do it, either government experts or private laboratories. In general this work has heretofore been done by college laboratories, the professors working for the pleasure of the work, and freely publishing all they found. Book after book has been published on chemical and physical constants, and probably three-fourths of all the data has been furnished by college and university professors and their assistants.

Another line which is a little further removed and which does not touch steel treating particularly, is the vapor tension of metals. They have tension just as much as water has. You can boil them, and below their boiling point they have vapor tension down to their freezing point. I have even

calculated their vapor tensions at zero degrees centigrade. A paper was read in New York recently at the meeting of the American Mining and Metallurgical Engineers on "Heating Steel in Vacuo." The author said that in some cases iron vapor condensed, and the deposits contained manganese and copper. He also found in some specimens that iron volatilized from one part of the specimen and deposited on another part a little way off, showing there were present two kinds of crystals of iron, having different vapor tensions. You will not find much about this in books. But in 5 or 10 years we will wonder how we ever got along without knowing these facts, because they concern operations which are frequently done, and they help to explain their "Why" and "Wherefore;" yet at the present time we have almost no information at all about them.

Another thing we might discuss is the question of the thermochemistry of metals, for instance, the heats of combination of the metals to form alloys. We know the heat of combination of hydrogen and oxygen to form water; but we do not know the heat of combination of copper and zinc to form brass. If we knew the heats of combination of the various metals, these would probably give us some indication of the stability of their alloys, which information would be very useful.

Another topic of interest would be the equilibrium of iron and iron oxide against carbon monoxide gas. How quickly will various alloys oxidize in an atmosphere of carbon dioxide? Quite a long paper was read recently in New York on the question of the equilibrium of iron and iron carbide with oxygen and the iron oxides. Still another subject for investigation would be heat conductivity, or the power to conduct heat. Where does that come in? First of all, where could we find data about it? If we look in books of tables, we will perhaps find a little data on the conductivity of iron at low temperatures. What about it at high temperatures? When we heat a piece of iron, it heats from the outside. The heat is transferred from the outside to the inside; the rate of transfer depending upon the heat conductivity. If we have the proper data on the heat conductivity of iron at all temperatures, we can calculate how quickly the iron would heat up. You say "We can find out anyway." So you can by experimenting, but you should always check experiments with engineering calculations if you have the data. And suppose you can't make the experiment? You can calculate many things. An engineer calculates a bridge before he builds it. You can get ahead of the game if you have the proper data. Heat conductivity will help to calculate the rate at which metals heat.

Another problem is heat emissivity. At what rate does iron radiate heat? The Bureau of Standards has been working on this. What advantage would there be in knowing the rate at which it radiates heat at different temperatures? Suppose you take a piece of heated iron out of the furnace and start to work it. It cools from the outside. The inside can only cool by transmitting heat from the inside to the outside. This depends on two things—heat conductivity and heat emissivity; the latter radiating it from the outside. If we had these data complete, we could calculate it for any kind of a piece of iron, of any size and any temperature. Before we experimented with it we could calculate at approximately what rate it would cool. By this method of getting the fundamental data you can often predict what is going to happen; you can project into the future and tell what is going to happen before you try.

Let us consider the electrical conductivity. We know the electrical conductivity of iron at low temperatures, up to red heat. We want data beyond that very much; we want to know the electrical conductivity of melted iron. Electric furnaces use melted iron as their resistor, the heat developed being dependent on the resistance of melted iron. What is it? I remember about 10 or 15 years ago there was no figure published. I made a guess, a long-shot guess. I extrapolated the value of the electric conductivity of iron in the solid state at red heat up to the melting point. Some other metals double their electrical resistivity at the melting point when melting, so I halved the conductivity. I came within 10 per cent of the value afterwards determined. My guess at least gave me something to go on with; and, anyway it was not such a wild guess.

There are such things as critical constants but no one knows much about them. Water has a certain critical temperature at which the liquid passes into the vapor with the same density. There are critical temperatures, critical pressures, and critical volumes. I do not think we know them for any metals, but they all have them. I tried to calculate them for mercury. What use are they? When we want to calculate many of the chemical properties of metals we can calculate them from the critical constants more easily than from anything else. In fact this is true of many of the physical properties of the elements. If we had those critical data we could theoretically go back and get the specific heat, the latent heat of fusion, the latent heat of vaporization, etc.

There are a few other things I wish merely to mention; one is the subject of gases in steel. We know that water dissolves gases but if you look in books you will find that water dissolves oxygen, carbon dioxide, and nitrogen and the different amounts given at ordinary temperature and at higher temperatures. Look in books to see how much oxygen, carbon dioxide, carbon monoxide, or nitrogen, iron will dissolve. It dissolves them. Most metals dissolve gas. We know that from experience; but how much? How is it given out? Under what conditions can it be frozen out? We have no information at all of a quantitative nature parallel to what we have for water. So we want to determine it. If we had that data we would be a long way toward settling the question of the presence of gas in metal—in solid metal—and blow holes in castings, etc.

Another subject is the viscosity and fluidity of metals. We should know these in absolute numbers; we should know the value in absolute C. G. S. units. I looked in Landoldt and Bornstein's book of tables under this subject, and found that mercury was the only metal mentioned. When we consider how many metals are cast into castings, and how important is the fluidity of metals, how they have to run up into little narrow cracks—if we only had viscosity or fluidity data at different temperatures, we would know the reasons why they behave as they did at different casting temperatures. What an immense amount of exact information is to be obtained, which we do not have at the present time.

I almost hesitate to mention anything about the alloys of iron because there are so many of them. We do not have complete data on iron itself; the alloys are practically all outside; all unknown. The valuable properties we know about pure iron are yet to be determined for its alloys.

There are a couple of other things I might mention. X-ray pictures through iron. There is a line of investigation for someone. In fact, if we could take pictures right through iron, they would reveal its internal struc-

ture, blow holes, and nonmetallic inclusions. The General Electric Co. is now working on this problem and we can look through ½-inch of iron and see its internal structure. With new machines now being perfected it is expected to be able to see through 1 to 2 inches of metal. Any hidden defects could probably be detected without any damage to the tools.

Another topic which may come up in the future is X-ray interference pictures. We can take a photograph of a crystal which will show the molecular structure. A crystal of iron has had its molecular structure pictured. The points shown in the photograph indicate the atomic grating or scaffolding. There is a field there for the investigation of steels which are other than pure iron, to see if we can find what effect sulphur, phosphorus and other elements have on the molecular structure. In the future we may simply apply this method to the alloys of iron to determine why they act as they do. It will give us further insight into the "Why" and "Wherefore."

DISCUSSION OF DR. RICHARD'S PAPER

MR. WALKER: In my experience with steel the question of rust prevention has come up. Various trades seem to have considerable difficulty in preventing rust. I got into conversation with a man on the train the other day and we talked from Cleveland until the train arrived at Springfield. This gentleman thought rust formation might be prevented by the kind of heat treatment given. If this is so it would be a good thing for other lines of business. You often find underneath a coat of paint that rust formation takes place. This would be a good case for structural steel work, and it would be a good field at some future time for heat treaters in the line of structural steel.

MR. BROOKE: I was specially interested in one phase of the subject discussed by Dr. Richards, that which comes up in designing furnaces for heat treating. We have found a difficulty in obtaining specific heats of the metals of the steel group at normal temperatures, while accurate curves showing specific heats against rising temperatures up to, say 1800 degrees Fahr. are extremely difficult to obtain.

Another difficult datum to obtain is the rate of absorption of various metals and the influence on this of the relation of mass to surface to surface exposed, for any particular piece of the steel. The variation of the latter relation can be seen by taking, for instance, a 15-ton gun ingot when the relation of mass to surface may be as high as 250 pounds per square foot, while in a small casting this relation may easily be only 7 pounds to the square foot.

This information is of special importance to the engineer in designing a modern electric heat treating furnace, so that he may work to a definite and accurate time and heat cycle. It is of importance to the metallurgist in charge of heat treating so that he may know accurately when his work is thoroughly soaked.

There is an important economic feature in this. It has been common practice, especially in the steel industry to soak the steel to be treated. This practice is usually a matter of playing safe, because there has been no true method of ascertaining when the steel itself is at the desired temperature throughout the whole of its mass. The length of soaking is defined by past experience and playing safe at the expense of fuel consumed.

With the modern electric furnace, in which the heat gradient is low and equipped with modern control instruments, soaking for the above reason is eliminated as a two-point instrument, recording the temperature of the uniform source of heat against the temperature of the work, gives two curves which will converge as long as heat flows from the former to the latter. As soon as these curves are parallel, there is no longer any flow of heat and the temperature of the work must be uniform throughout.

Dr. Richards has started some excellent technical propaganda and I am sure he will be pleased to hear that one of the large heat treating furnaces now being installed in the Philadelphia vicinity, is to be painted on every one of its 17,000 square feet of surface with perfect white enamel.

DEVELOPMENT OF MEASURING INSTRUMENTS FOR METALLURGICAL USE

By Morris E. Leeds*

(A Paper Presented Before the Philadelphia Chapter)

The American Society for Steel Treating is a young one and most of its members are young, but in the brief span of its existence a great change has come over the practice of heat treating. The old-fashioned heat treater with his inherited traditions and prejudices practically held the field a very few years ago. That old type of man is fairly well represented by one I knew in a factory not very far from here not many years ago, who said that although he could not tell the temperature of a piece of steel with anything like his father's precision, he could nevertheless with the unaided eye determine with greater accuracy than with any "phrenometer" at what temperature the steel should be quenched. I do not wish to underrate the skill and achievement of such as he, but when we realize the tremendous demands that have been made on the industries in which heat treating performs an important part during the last few years, we realize how very fortunate it is that the art is now resting on a more secure foundation.

Heat treated steel products enter into our economic life to such a tremendous extent in value of material, in range of uses and in range of sizes from armor plate to parts for watches, that it is imperative that the art of heat treating should rest on a secure foundation of ascertained scientific facts. You are to be congratulated on having played a very important part in bringing about the transition from dependence on inherited tradition to soundly based engineering.

Our chairman mentioned something about the part which instruments play not only in the scientific side of this work, but also in its application in the factory. I hardly need to remind you of that; but I think that it is true in this particular field that there is hardly a step in any direction which is not accompanied with some kind of measuring instrument or laboratory apparatus. From the original scientific work in laboratories on through actual operations in the factory you are using in some manner measuring or other instruments. Temperatures are to be measured, critical points determined, chemical analyses made, hardness, tensile strength, elongation and many other properties determined—for all of these instru-

*President, Leeds & Northrup Co., Philadelphia.

ments are needed. So I want to devote the few minutes at my disposal to telling you something about the Association of Scientific Apparatus Makers of the United States, to which the chairman referred.

A much younger society than yours, we envy you your strength, your members and your enthusiastic meetings. In comparison we are a very feeble folk in all these respects, but like you we are associated for the advancement of our art, and like you we want to be of service; thus we want to bespeak your co-operation in helping us to accomplish these ends. We are divided into several sections. The one nearest to most of your work is the Pyrometer Group. We include in that practically all of the manufacturers of pyrometers in this country, and we are associated for the purpose of improving that branch of industry so that we can render better service. You might be interested in some of the particular problems we have had under consideration.

One that early claimed our attention was the possibility of standardizing thermocouple materials. If it should be possible so to standardize these materials that all couples made of any particular combination, for instance, iron and constantan, would show the same temperature electromotive force relation throughout their range, then all such couples could be used interchangeably with any reading or recording instrument calibrated for iron-constantan couples. You could interchange couples, whether from the same company or not, in the same way as the microscope of one manufacturer can be used with the objective of another. We found, however, that several standards were in use, and so much material was out that it was not practicable to standardize iron-constantan. It is possible to make a partial standardization of platinum and platinum-rhodium. Copper-constantan couples are coming into use for low temperatures, and a standard electromotive force temperative relation for these has been adopted, to be used by all makers. Chromel-alumel is also standardized, and if new couple materials are introduced it is expected that they will be standardized.

Our association hopes to publish a journal. We have little prospect of having as successful a one as yours from the standpoint of volume of matter printed and amount of advertising carried. The production of good instruments in the United States will be stimulated by having a good journal devoted to the subject. We are developing the plans for this journal in close co-operation with the Bureau of Standards and the National Research Council because we wish to make sure that the journal shall not become simply a trade organ, but that it shall be edited under the control of people interested only in advancing the art of instrument making in the United States, who will see to it that it is used for presenting new and worth while designs and information in regard to instruments, no matter from what source that information comes.

A subject on which we should particularly like to have your interest, and perhaps assistance, is the tariff. As we see it, certain branches of instrument making practically will be impossible in this country unless they are protected and pretty well protected. We do not see how the makers of optical glass, for instance, who had done almost nothing up to the time of the war, can continue to make optical glass successfully and assume the expenses of developing and producing the new kinds of glass needed in small quantities for making optical instruments unless they are in some way supported. I wonder whether you realize how exceedingly important optical glass is and how wide a range of measuring instru-

ments are absolutely dependent on it. Every instrument which has anywhere about it a small telescope, microscope or prism depends on the optical glass manufacturer.

I heard the statement made a short time ago, and I have no reason to doubt its correctness, that if it had not been for some considerable stocks of optical glass in the United States when war started, and supplies from the Allies, we should not have been able to make effective use of the guns on our battleships and land batteries because we should not have been able to make instruments with which to aim them properly. That is just one illustration of how the little technical field of instrument making links itself up with matters of great national importance. We believe that the technical development of our manufacturing processes in the United States cannot proceed on a really sound and healthy basis unless we also produce the instruments on which these processes to so large an extent depend.

It is not only in these rather important matters of policy that we want your interest. As individual instrument makers we want your co-operation in working on the particular instruments that will meet your special problems. We can study the characteristics of instruments and the fundamentals of design in our shops and with the help of the Bureau of Standards and other scientific laboratories, but we cannot give them the particular forms which will best suit them to meet your conditions unless we have your co-operation in presenting your problems and needs. In this respect, I think more than any other, the members of your Society and the members and representatives of ours can work together to mutual advantage so as to develop the great industry with which you are associated and the little but very important one which interests us, and so play our part in promoting the technical development of the country.

WORLD CONDITIONS AND THE DEVELOPMENT OF FOREIGN TRADE

By Richard Spillane*

(An Address Before the Philadelphia Chapter)

The speaker has just come from a dinner at the Bellevue Stratford hotel and for which he had a fair share of responsibility. Probably it was the most remarkable dinner that ever has been held in this city. We had practically all the foreign students of the University and other educational establishments of the metropolitan Philadelphia as our guests. Fifty-two nations were represented there and practically all of their native costumes. This gathering was by design. We wanted to draw the people of the earth closer in their relation to Philadelphia and to the United States. We want to use the basis of hospitality to promote good will, education and trade. It is proposed to have a gathering of this sort every year. It is also proposed to take these students into all of the large banks to see how the animal performs. It is further proposed to take them into the Midvale Steel & Ordnance plant, into Disston's Saw Shop, the Miller Lock, the Stetson Hat, and any other establishments here that will broaden their knowledge of the works of America. We are going to endeavor to influence Boston, New York, and all of the other centers of education in this country to which the foreign students flock, to follow our example—and all on a peace basis, on a basis of good business.

*Business editor, *Public Ledger*, Philadelphia.

I don't know whether it is too far a cry to say that out of gatherings such as this of tonight and the others that will be the natural attendants to that, that a great deal of trade, a great deal of business—even in your lines—will develop. We have only a hazy idea of the wonderful transformation, reformation, and majestic change that has come over this world in the last 20 years. If anybody had said in 1876 when Mr. Bell explained the telephone in this city of ours, that in 1920 for example, the human voice or a message would float over the seas on an ethereal wave, that man would have been considered crazy. If any one had prophesied that it would be possible to fly across the seas in one-half, possibly one-third, or maybe one-quarter the time it now takes the fastest ship, he would have been a dreamer.

More progress has been seen in the last 20 years than was seen in the previous 200. If you think of the phonograph, or think of the wireless, or of the telephone as it has been developed over what it was 20 years ago; if you think of all that has come to pass in the last 20 years, it is not too much to say that in the next 20 years the progress will be even greater.

You are going to have wonderful works of development if this country of ours meets the task that is going to be put upon it within the next few years. We will have to do a great work of financing; we will have to finance Asia, Africa, South America, Central America, and Europe. We will have to dig into our socks, stretch the dollar; we will have to do works of legerdemain with money; and we can do it if our men of finance measure up to the genius of the American man.

I was over in New York recently and had laid before me a project in South America that is colossal. I would have thought it was visionary but for the fact that the man at the head of it is of proved greatness, and the financiers interested in it—well, they stand second to none in America. The man is William Braden of the Braden Copper Co., and financial secretary of the Guaranty Trust Co. I went over the reports of the geologists, and unless these men are mistaken—and they had reports of 40 of the most eminent in the world—they have the greatest quantity of oil known. The original pool was in south Bolivia and north Argentine—one pool—another was in west Argentine and three more in south Argentine. They have one section of country in Bolivia of about 5,500,000 acres. It is in a section so removed that although the natives have been using the oil for God knows how long—a 100 years surely, maybe much longer—although they have been using seepage oil for illuminating purposes, there has been practically no development. It is probably a far greater oil pool than that of Mexico which is a mine.

These people contemplate carrying ocean ships 1000 miles up the River Plata and its branches, building 1000 miles of railroad, building great refineries, and other projects of the same character, but not so much in their immediate neighborhood. Their initial outlay they expect to be $50,000,000; but that will be only a starter.

If this plan comes to accomplishment you can expect argosies of business in the South Atlantic and South Pacific comparable only to what you have in the North Pacific and North Atlantic today, for if they have the great element of power, oil, in the quantity that seems probable, this is going to revolutionize trade instantly in that part of the world. And it will create a demand for steel such as you never expected from that quarter.

According to the plan of the youths, of 52 foreign nations—youngsters—the pick of their country, will be sent here to be educated in this land of ours. About 600 foreign students now are in the metropolitan Philadelphia; about

6000 in the United States. I think it is about time we showed them our hospitality, showed them our friendship; showed them the inside of all of our structures that it is necessary for them to know, and have them go back to their own lands as boosters, agents, and salesmen for this country of ours. I think this is about as easy and cheap a way for us to "sell ourselves," as the saying is, to the foreign customer.

Very few I believe have any conception of what is going to be done in other lands within the next half century, or what a tremendous draft there is going to be on this country for material. Some of the projects in connection with China are tremendously big and we will have to do the financing. This should not be bothersome, however, in view of our work in developing the railroads of America, the British, the Dutch, and the French. Those who really put up the bulk of the money never lost anything in the long run. We are in a much better position to avoid some of the pitfalls into which they sank. We are loath to venture into foreign territory; but we have got to do it. This world of ours is sadly mixed. There is no country that is self-contained. We have argued to ourselves that this country was; but it is not. Unless other sections of the earth profit, we are not going to profit to the extent we ought. There cannot be any loss in any section without all sections feeling it to some degree. There can be no work of development, no work of progress in any section of the earth, without our sharing in it to some degree.

You are going to see an era of railroad building in other countries We are not going to see as much in this country as we should; but we are going to see it in other countries to a very great extent. One of the gentlemen going to speak over at that gathering tonight is one of the ministers of China. If the Chinese can get money, and they have to get it, they are going to do great works in hydroelectric development; works of building; works of development of every kind; they are going to make such improvements as will transform that wonderful land in the present century. It is the same to the south of us. The only thing we have to do to avoid trouble is to stay out of war—that is the only thing. I was at the Bellevue Stratford some time ago when Sir Auckland Geddes said that if another war such as the last one, took place in 20 years, civilization would fall. The same thing was said a little later by Lord Grey when a degree was conferred upon him at Glasgow University. The degree was to have been conferred in July, 1914, but something happened to defer its bestowal until 1921. He uttered the exact sentiment that Sir Auckland did. We today are the leaders, industrially, morally, financially, for the world. We will have to be the suppliers for many decades.

No one who knows the real situation in Europe is optimistic. The whole structure there is wrong. Europe is not only divided into more than 40 territorial units with each unit trying in its own selfish way to advance itself to the disadvantage of its neighbors; but it is living in traditions of hate. It is looking backward instead of forward. It is craving the unattainable and ignoring the attainable. It may be an absurd dream, but the only way I can see that Europe will ever settle these horrible wrongs and forget the past is to fabricate a structure somewhat after that which we have here, and have a United States of Europe. If they don't do something of that sort, they will go from worse to worse. You can imagine what Europe is if you can picture this country of ours with its 48 states with each one having an economic barrier against the other. Suppose Pennsylvania could not ship goods into Ohio, or into New York, Maryland, West Virginia, or New Jersey, without

the goods paying tribute at the territorial division to the other country. It is the most horrible mixture of races of the earth. It is the most horrible mixture of hates of the earth.

Many of those people figure the things to do from the ideas and hates of nearly 10 centuries ago, and it is going to be very, very hard to wean them away from their old ideas. All men of prominence who have been abroad and with whom I have spoken, are not one-tenth as hopeful of Europe as they are of Asia, South America, or Africa. We will have to help Europe; we will have to help it largely, not only largely with money, but with material and with philosophy different from that which has obtained there for these many years. Some of the men who have been in central Europe tell me that the civilization of central Europe is at least a century back of that of ours, and that industrially only in spots do they approach anything we have here. But you have a fallow field. There is, however, a wonderful field in foreign lands; and while we will have to do all within our power to aid the people of Europe, not only for their own good, but for our own safety; it is best for us to expend our best efforts on lands where hates are not so deeply rooted and the prospect is far more pleasing.

TESTS OF CENTRIFUGALLY CAST STEEL

By Dr. George K. Burgess*

(A Paper Presented Before the Philadelphia Chapter)

In 1918, the Bureau of Standards had occasion to examine several hollow, steel cylinders made under the direction of W. H. Millspaugh by his centrifugal casting process. The manufacture of these centrifugal castings was carried out under somewhat adverse conditions in two steel foundries which of course, due to the limited experimental nature of the trials, could not have developed the refined technique that practice would give, nor were efforts made to produce high grade steel for these tests.

The cylinders were cast in a machine revolving about its horizontal axis. The outer surface of the castings, of walls from ½ to 3½ inches thick, thus were against the mold and turning faster than the free inner, cylindrical surface which was last to freeze. The outer surfaces were fairly smooth but the interior surfaces were rough.

The results, comparing the several grades of steel in the condition as cast and after heat treatment, are of considerable interest as indicating what may be expected for certain shapes from this method in the production of sound steel, that is, steel free from physical defects and chemical segregation, and thus with practically no waste material to discard. As will be shown, it is also a field particularly adapted to the elimination of forging and boring operations and the substitution for the former of heat treatment to produce the desired characteristics in the resulting product.

In all six castings were examined, samples from which were subjected to the usual mechanical tests both transverse and longitudinal, in the condition as cast and after various heat treatments. The characteristics of the metal with respect to internal stress, density, soundness, segregation, and micro-structure were also studied.

In Figs. 1 and 2 are shown the dimensions of the castings and the location of samples for test, except for No. 7, which was a cylindrical ring of 12

*Chief of the Department of Metallurgy, United States Bureau of Standards, Washington.

inches diameter and one-half inch wall thickness, from which longitudinal flat tensile bars 12 by 1 x 9/32 inches were taken. The tensile bars from all other castings were standard 2-inch round bars. Samples for chemical analysis were taken from ring turnings for castings Nos. 4, 5 and 7, and for Nos. 1, 3 and 6 from longitudinal borings in zones numbered 1 to 5 from outside to inside of the casting, as shown by the sketches in Figs. 1 and 2.

In Table I are given the results of the radial surveys for hardness and chemical analysis. It will be noted there is a gradual increase in carbon from the outside to the inside surface for all castings, this increase ranging from 0.02 per cent for No. 3A to 0.09 per cent for No. 5. This increase appears to be roughly proportional to the carbon content, or the percentage variation in carbon remains practically constant. The nickel and phosphorus appear to follow the carbon very closely in their behavior as to segregation; manganese and silicon, however, are nearly constant across the radial section; while sulphur, although somewhat erratic, in general is distributed similarly to carbon, as is also copper, although present in quantities less than 0.1 per cent. The hardness surveys, brinell

Table I
Hardness and Chemical Surveys

Casting Number and Wall Thickness Inches	Zone	Brinell	Sclero-scope	Carbon Per cent	Manganese Per cent	Silicon Per cent	Sulphur Per cent	Phosphorus Per cent	Nickel Per cent	Copper Per cent	Chromium Per cent
No. 1	1	186	25.8	.44	.44	.47	.024	.011	2.33	.084	...
	2	186	24.9	.48	.44	.47	.030	.013	2.35	.089	...
3½	3	187	25.0	.46	.44	.47	.032	.013	2.32	.085	.04
	4	187	25.2	.46	.44	.48	.032	.014	2.36	.094	...
	5	196	25.7	.50	.44	.47	.034	.015	2.39	.089	...
No. 3 A	1	160	22.3	.33	.54	.19	.022	.015	2.66	.051	...
	2	164	22.2	.32	.55	.19	.030	.014	2.67	.053	...
3	3	167	22.4	.32	.55	.19	.032	.015	2.70	.051	.04
	4	167	22.6	.34	.57	.19	.034	.016	2.75	.055	...
	5	160	22.3	.34	.57	.20	.030	.017	2.70	.054	...
No. 3 I	1	158	21.9	.30	.55	.20	.031	.012	2.66	.062	...
	2	159	22.0	.30	.55	.19	.030	.013	2.67	.062	...
3	3	158	22.0	.30	.55	.20	.030	.015	2.68	.067	.04
	4	156	22.5	.34	.57	.20	.030	.017	2.76	.068	...
	5	184	23.9	.35	.57	.21	.030	.018	2.70	.065	...
No. 4	0	...	....	.16	.47	.27	.054	.045	....	....	...
	1	125	19.7	.16	.50	.29	.045	.033	....	....	...
	2	...	20.4	.16	.51	.28	.045	.033	....	....	...
2¼	3	128	20.6	.17	.50	.28	.049	.037	....	....	...
	4	...	20.0	.18	.50	.29	.053	.038	....	....	...
	5	121	19.2	.21	.52	.29	.060	.043	....	....	...
	6	...	....	.18	.40	.22	.066	.059	....	....	...
No. 5	1	249	63.5	.64	.56	.65	.033	.014	2.94	....	...
	2	...	60.6	.65	.56	.65	.032	.015	2.92	....	...
3¼	3	248	58.0	.63	.55	.64	.029	.015	2.93	....	tr.
	3	...	55.5	.63	.55	.64	.031	.017	2.93	....	...
	5	245	57.0	.72	.60	.68	.033	.017	2.90	....	...
No. 6	1	164	23.4	.32	.56	.19	.034	.015	2.69	.059	...
	2	166	23.4	.33	.56	.19	.035	.015	2.75	.058	...
3½	3	161	23.4	.31	.56	.19	.039	.015	2.72	.059	.04
	4	167	23.8	.33	.57	.19	.032	.015	2.76	.064	...
	5	191	25.2	.35	.57	.19	.033	.016	2.81	.064	...
No. 7	1	...	....	.22	.54	.26	.026	.013	....	....	...
	2	123	....	.21	.53	.25	.026	.014	....	....	...
½	3	...	....	.25	.55	.25	.026	.016	....	....	...

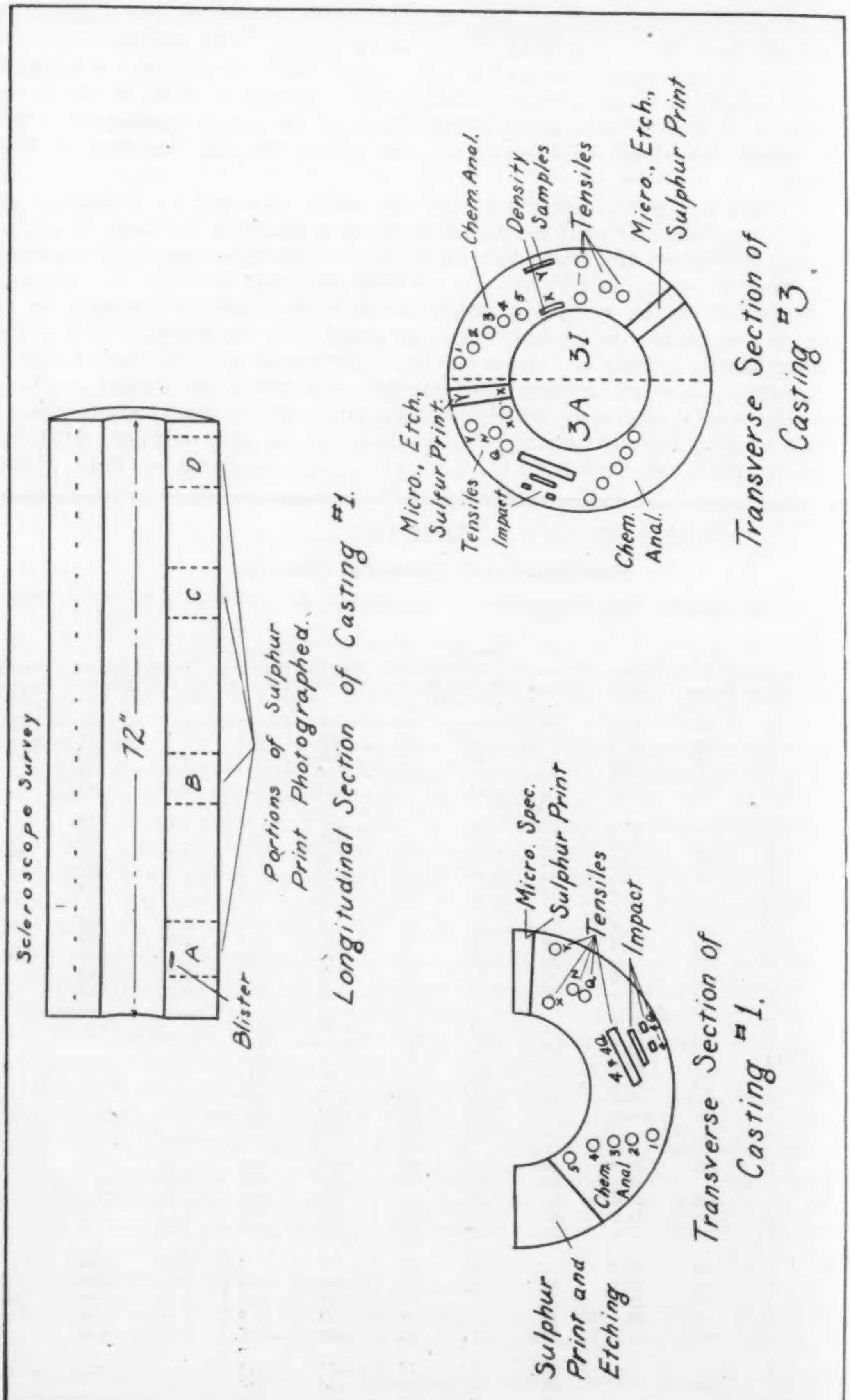


Fig. 1—Test Sample Sketches of Centrifugally Cast Steel Pipe

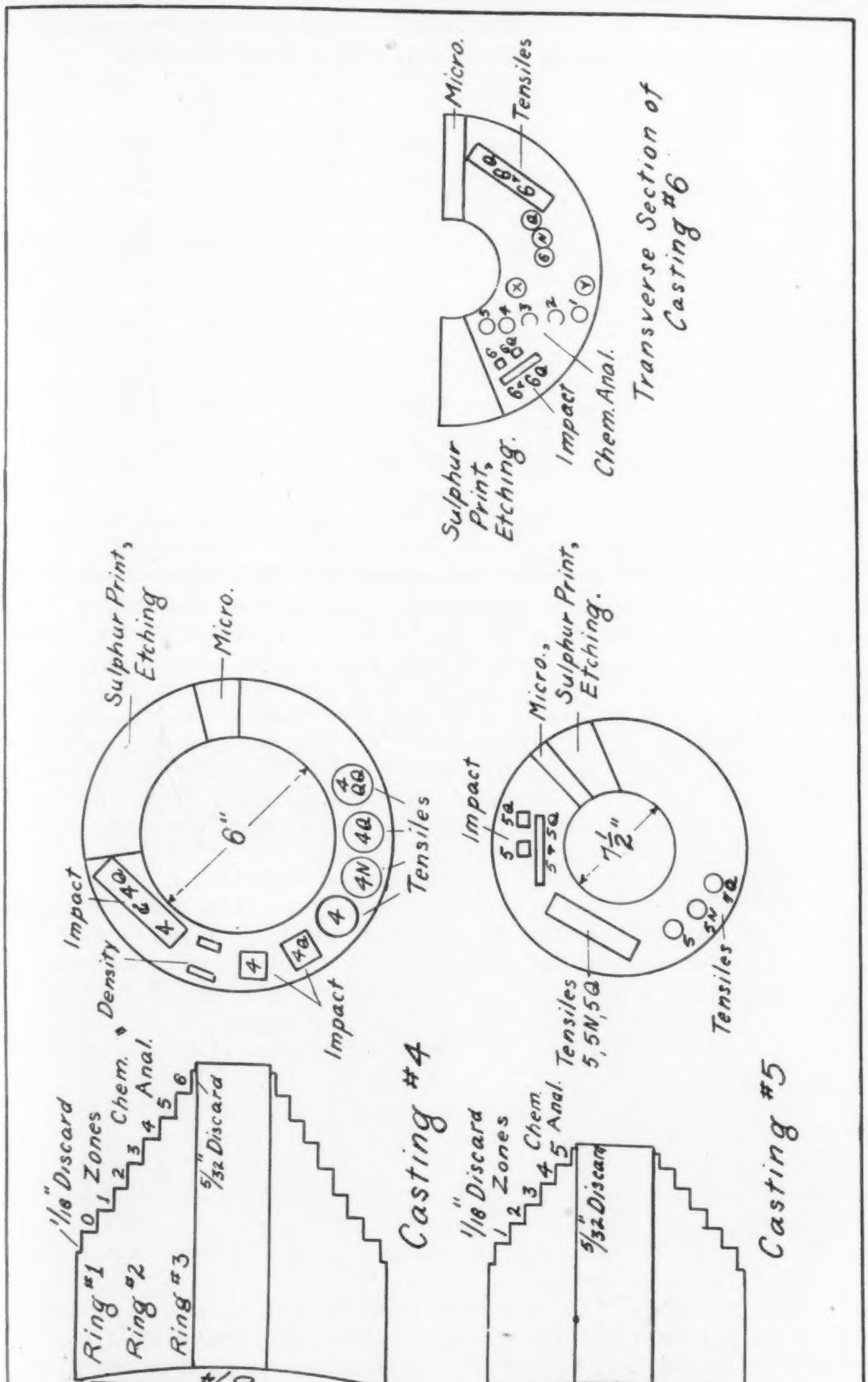


Fig. 2—Test Sample Sketches of Centrifugally Cast Steel Pipe

Table II
Nature of Stresses in Concentric Rings from Castings

Outside Ring	CASTING NO. 4 Before Splitting Inches	CASTING NO. 4 After Splitting Inches	CASTING NO. 4 Difference inches		CASTING NO. 5 Before Splitting Inches	CASTING NO. 5 After Splitting Inches	CASTING NO. 5 Difference inches	
Outside diameter....	8.080	8.080	0.020	contraction	10.765	10.750	0.015	contraction
Inside "	7.280	7.265	0.015	"	10.205	10.185	0.020	"
Between punch marks, diameter	7.650	7.625	0.025	"	10.515	10.505	0.010	"
Between tangential punch marks outside	2.030	1.990	0.040	"	2.015	1.985	0.030	"
Between tangential punch marks middle.	2.000	1.960	0.040	"	1.985	1.950	0.030	"
Between tangential punch marks inside..	1.920	1.890	0.030	"	1.990	1.950	0.040	"
Middle Ring								
Outside diameter....	6.840	6.830	0.010	"	9.530	9.565	0.035	expansion
Inside "	6.560	6.550	0.000	....	9.080	9.095	0.015	"
Between punch marks, diameter	6.920	6.920	0.000	....	9.345	9.355	0.010	"
Between tangential punch marks outside	1.985	1.985	0.000	....	2.000	2.015	0.015	"
Between tangential punch marks middle.	1.955	1.960	0.005	expansion	2.005	2.020	0.015	"
Between tangential punch marks inside..	1.900	1.900	0.000	....	2.000	2.015	0.015	"
Inside Ring								
Outside diameter....	6.790	6.780	0.010	contraction	8.515	8.560	0.045	"
Inside "	5.980	5.975	0.005	"	8.360	8.405	0.045	"
Between punch marks, diameter	6.425	6.445	0.020	expansion	8.160	8.175	0.015	"
Between tangential punch marks outside	1.970	1.965	0.005	contraction	1.985	2.025	0.040	"
Between tangential punch marks middle.	1.955	1.950	0.005	"	1.975	2.005	0.040	"
Between tangential punch marks inside..	1.945	1.945	0.000	....	1.975	2.005	0.040	"

and scleroscope, follow closely the chemical segregation, the higher numbers occurring on the inside layers. A hardness survey with the scleroscope made midway along a longitudinal section the 72-inch length, of casting No. 1 at 3-inch intervals, shows a gradual increase in hardness from end B to the middle, 24.2 to 25.3, and then nearly uniform hardness for the second half, or from center to end A. The position of the scleroscope survey is shown by the longitudinal section of casting No. 1, Fig. 1. The chemical analysis of the *A* and *I* sections, separated by 60 inches in the *C* casting, apparently shows evidence of longitudinal segregation but this is so very slight as to be uncertain.

A narrow circumferential strip 2 inches long, 1 inch broad, and 1/4-inch thick was cut from the outside and from the inside of a transverse ring from the nickel steel casting No. 3*I* and from the low carbon casting No. 4 and used for determination of density. The results are as follows:

	Grams per cubic centimeter at 23 degrees Cent.	Difference
Casting No. 3*I* outside	7.838	
Casting No. 3*I* inside	7.834	+0.004
Casting No. 4 outside	7.834	
Casting No. 4 inside	7.726*	+0.108

*The low density of sample No. 4 (inside) is probably due to the presence of a series of very fine pits or blowholes in this sample. These holes occur about 1/16 inch from the inner surface of the casting, where their presence was actually observed.

Three concentric rings, 3/8 inch wide radially and ½-inch thick longitudinally, were cut from the No. 4 casting which was low carbon electric furnace steel annealed, one ring from the outside, one midway, and one from the inside of the cylinder. Accurate measurements were made of the outside and inside diameters of each ring, the distance between diametrically opposite punch marks and the distance between three sets of

punch marks 2 inches apart tangentially. A cut was then made by a hand hack saw midway between the 2-inch tangential marks and at an angle of 90 degrees to the diameter measured. When split thus the outer ring contracted visibly but the middle and inner rings appeared to undergo no change. Similar rings were cut from casting No. 5, which was high carbon nickel steel not annealed, measured and cut in the same manner as those from casting No. 4.

The measurements taken before and after cutting these concentric rings and the amount of expansion or contraction in each case are given in Table II and indicate the nature of the stresses in the outer, middle and inner zone. A rough computation gives the compression at outside ring of casting No. 4 as 48,000 pounds per square inch. For No. 5 the compression at outside ring is 31,000 pounds per square inch and the tension at inside ring is 47,000 pounds per square inch. These internal stresses are of the order of the elastic limits of the material, and as would be expected, the outer zone of the casting is in compression.

Turning now to the question of the improvement of these castings by heat treatment, in Table III are given the details of the treatments to which material from their castings were submitted, and in Table IV are grouped the mechanical properties associated with the respective treatments. The location of the specimens is shown in Figs. 1 and 2. It should be recalled that castings Nos. 1, 3, 4 and 7 were annealed as a whole before any tests were made on them, while castings Nos. 5 and 6 were examined first in the condition as cast. The test pieces from 3A

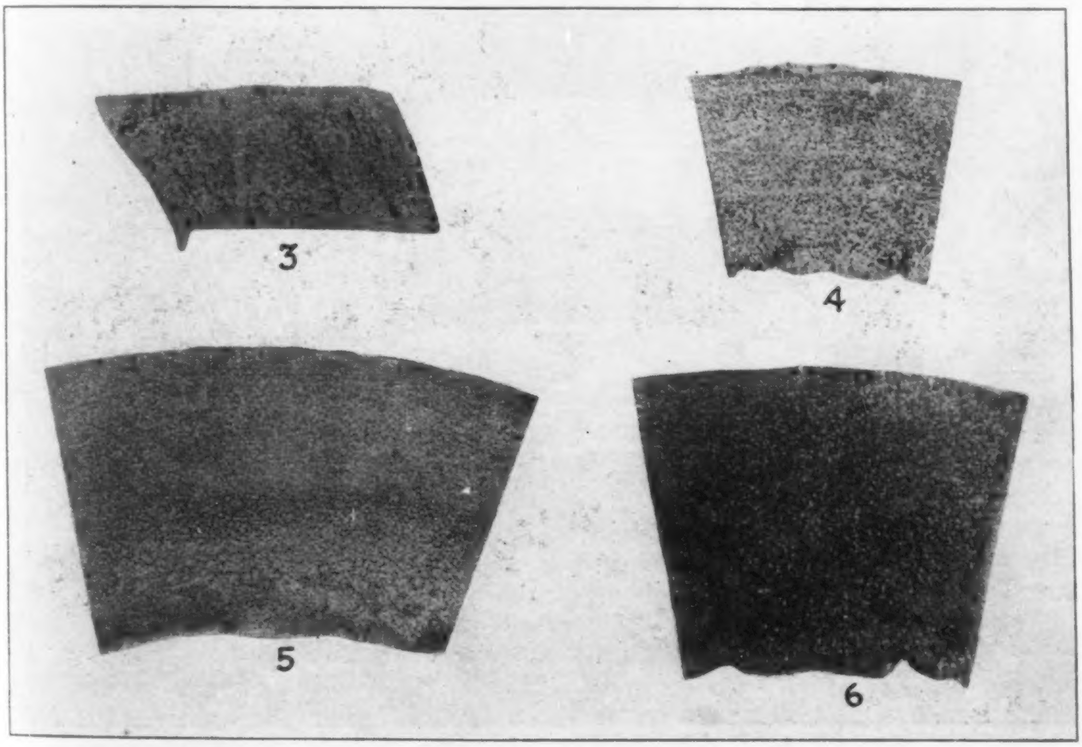


Fig. 3—Sulphur print of a short section of Casting No. 1 showing a high sulphur outer zone and low sulphur middle zone. Fig. 4—Sulphur print of a transverse section of Casting No. 5 showing small high sulphur areas in inner zone and several circumferential low sulphur bands in middle and outer zones. Fig. 5—Cupro-ammonium-chloride etching of transverse section of Casting No. 1, practically free from fir-tree crystals but showing high carbon circumferential bands in inner zone and low in outer. Fig. 6—Cupric-ammonium-chloride etching of transverse section of Casting No. 5 × 1½. Structure is coarse grained with higher carbon areas in inner zone.

and 3*l* were from pieces of the same casting 60 inches apart. An examination of Table IV shows that most samples show good tensile strength for their composition and treatment and also that there is no marked difference in values for longitudinal and transverse specimens. The values for the Izod shock test are somewhat erratic. The advantages of heat

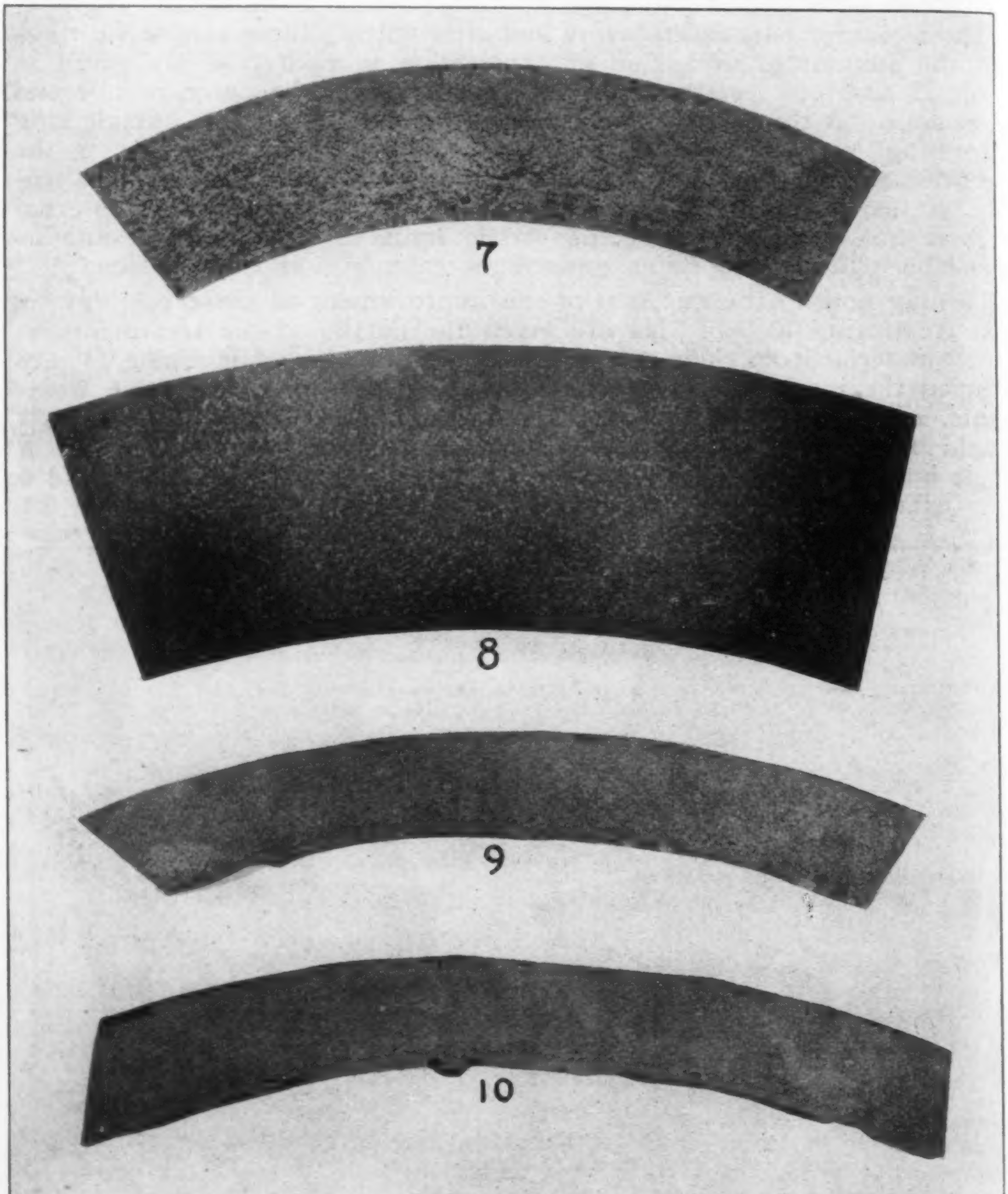


Fig. 7—Sulphur print, actual size of transverse ring from Casting No. 4. Little variation in sulphur content, slightly more along inner edge than outer. Small local segregations visible. Fig. 8—Cupric-ammonium-chloride etching × 2 showing coarse grained structure. Fig. 9—Sulphur print, actual size, of transverse section of Casting No. 7 showing practically no sulphur segregation except at few small spots at extreme inner edge where small surface blow holes occur. Fig. 10—Cupric-ammonium-chloride etching, actual size. Transverse section, full thickness as cast, no machining, showing freedom from ingotism. Small surface blow-holes visible within 3/16-inch of surface. Inner zone slightly higher in carbon.

treatment, notably of the double quench and draw in improving both the resistance to shock and especially the ductility as measured by reduction of area, are strikingly manifest. Certain of these treated steel castings would appear to compare very favorably in their properties with those of forged material of the same compositions. For example, the ordnance requirements for gun forgings are: Elastic limit, 65,000 pounds per square inch; tensile strength, 95,000 pounds per square inch; elongation longitudinal, 22 per cent, transverse, 18 per cent; reduction of area longitudinal, 35 per cent, transverse, 30 per cent. These probably are more than met by casting No. *6QQ*, Fig. 2, which contains carbon 0.33 per cent and nickel 2.75 per cent; and almost met by others much as *3AQ* and *3IQ*,

Table III
Heat Treatment

Designation of Sample	Condition Received	Heat Treatment Given	Temperatures and Time of Heating: Heated then slowly cooled in air — Temp. Deg. Cent.	Held Hours	Temperature when quenched Deg. Cent. First	Second	Quenching Medium	after 30 minutes Deg. Cent.	Cooled in
1 N	Annealed	Normalized	800–805	2	...	...	......	...	Air
1 O	"	Quenched and drawn	800–805	2	795–800	...	Water	600	"
3 N*	"	Normalized	890–900	3	...	...	......	...	"
3 Q	"	Quenched and drawn	890–910	3	845–850	...	Oil	640–650	"
4 N	"	Normalized	910–925	2	...	...	......	...	"
4 Q	"	Quenched and drawn	910–925	2	915–925	...	Water	450–460	"
4 QQ	"	Double quenched	910–925	2	915–925	885	Water	440–450	"
5 N	As cast	Normalized	750–760	1½	...	...	......	...	"
5 Q	" "	Quenched and drawn	750–760	1½	760	...	Oil	700–705	"
6 N	" "	Normalized	850–860	2	...	...	......	...	"
6 Q	" "	Quenched and drawn	850–860	2	825–830	...	Water	675–680	"
6 QQ	" "	Double quenched	850–860	2	825–830	790–795	Water	680–690	"
7 Q	Annealed	Quenched and drawn	875–880	1	875–880	...	Water	510–515	"
7 QQ	"	Quenched and drawn	880–885	1	880–885	845	Water	435	"

*Specimens from A and I sections of No. 3 had the same treatment.

Fig. 1, which contain carbon 0.32 per cent and nickel 2.70 per cent. Again the properties of the casting with carbon 0.23 per cent are high for steel castings of that composition, and in the treated condition are superior to many of the results on hot rolled 0.20 to 0.25 per cent carbon steels and indeed are comparable to those of cold rolled steels of this grade.

It is of interest to note there appeared no flaws or visible defects, other than small blowholes near the inner surface, in the preparation of any of the test pieces for physical or chemical examination. The blowholes noted were always about 1/16 inch from the inner or free surface of the casting. No hard spots were found in any of the castings. Just next the inner surface of all castings, there is a layer not over 1/16 inch thick which appears to contain nearly all the physical and chemical discontinuities.

Sulphur prints and cupric-ammonium-chloride etchings were made on transverse sections of each casting. Some of the sections photographed are shown on Figs. 3 to 10 and represent the coarsest grained and most irregular portions of the sections examined. The 72-inch longitudinal section was finished and rubbed down with fine emery paper and a sulphur print taken along the entire length but no longitudinal segregation was found. At one point a hole or blister 2 inches long and 1/8 inch wide was found 3/32 inch from the inside edge of the casting and a distance of 6 inches from one end. The location of this blister is shown in the longitudinal section of Fig. 1. A nitric acid etching of the entire

section revealed nothing that is not shown in the sulphur prints. Any appreciable segregation in the casting occurs transversely from the outside to inside as shown in the etched transverse section.

Specimens for microscopic examination were cut from transverse, radial or longitudinal, and tangential sections of each casting as received and from transverse sections of the heat treated bars, in other words, after normalizing, quenching, and drawing, and double quenching

Table IV
Mechanical Properties

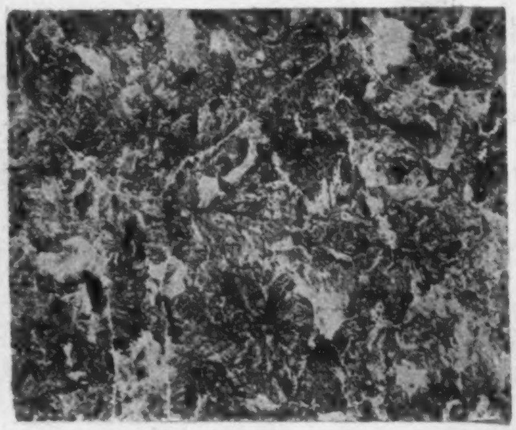
C and Ni.	No.	Yield Point lbs. per sq. in. Longitudinal	Yield Point lbs. per sq. in. Tangential	Ultimate Strength pounds per square inch Longitudinal	Ultimate Strength pounds per square inch Tangential	Elongation in 2 inches Longitudinal	Elongation in 2 inches Tangential	Reduction of Area Longitudinal	Reduction of Area Tangential	Izod Impact foot lbs. per Square inch Longitudinal	Izod Impact foot lbs. per Square inch Tangential	Miscrostructure	
C													
.44-.50	IX	54.3	....	91.2	.....	10.5	....	12.1	....	48.8	.....	Fairly fine with coarse	Ingotism Small blow holes
	IY	53.5	....	50.5	.....	9.5	....	8.9	....	.....	.....	ferrite boundaries, few	
Ni	IT	....	56.5	.....	89.5	....	5.5	....	7.5	.....	.....	slaggy areas	
2.32-2.39	IN	67.5	....	93.0	.....	8.5	....	12.5	....	.....	.....	Fine uniform	
	IQ	87.5	91.3	89.0	105.0	4.5	6.5	11.5	14.0	85.2	.....	Very fine uniform	
C	3AX	53.8	....	89.8	.....	7.5	....	12.1	....	252.0	187.0	Fir tree crystals and a few	
.32-.34	3AY	48.5	....	81.5	.....	16.5	....	22.0	....	.....	.....	slaggy ferrite areas.	
	3AT	....	50.7	.....	78.2	....	26.0	....	42.5	.....	.....		
Ni	3AN	59.8	....	95.7	.....	16.0	....	29.3	....	.....	.....	Fine uniform	
2.66-2.75	3AQ	67.5	70.2	98.0	90.3	21.5	20.5	47.4	42.0	309.0	704.0	Sorbitic, ferrite ghosts	
C	31X	52.5	....	88.7	.....	14.8	....	19.3	....	.....	.....	Finer than 3A	Very few slaggy areas
.30-.35	31Y	48.4	....	81.8	.....	27.0	....	41.8	....	.....	.....	Fairly uniform	
Ni	31N	60.5	....	89.1	.....	9.5	....	18.5	....	.....	.....	Fine, uniform	
2.66-2.76	31Q	64.5	....	95.5	.....	21.0	....	29.9	....	.....	.....	Fine, uniform	
C	4	40.0	....	61.5	.....	16.5	....	10.4	....	34.5	48.4	Coarse with thick	
.16-.21	4N	47.5	....	65.0	.....	11.5	....	18.9	....	.....	.....	ferrite veins	
Ni	4Q	60.0	....	79.2	.....	13.0	....	20.3	....	247.0	304.0	Fine, trace of veins	
....	4QQ	55.0	....	72.5	.....	12.5	....	24.5	....	.....	.....	Fine with streaks	
C	5	48.0	65.7	85.0	84.7	2.5	1.0	1.2	1.0	16.3	16.1	Coarse pearlite	
.63-.72	5N	77.5	....	129.0	.....	6.5	....	5.4	....	.....	.....	Fine slaggy pearlite	
Ni	5Q	96.4	92.3	115.0	113.3	16.5	7.5	21.7	10.5	142.0	183.0	areas	
2.90-2.94													
C	6X	47.5	....	82.5	.....	17.5	....	21.5	....	432.0	.....	Fairly fine; ferrite	
.31-.35	6Y	48.0	....	81.5	.....	17.5	....	28.5	....	.....	.....	veins, slaggy areas	
Ni	6T	....	50.0	.....	83.0	....	16.5	....	22.0	.....	.....	Ingotism	
2.69-2.81	6N	60.0	....	87.5	.....	14.5	....	22.0	....	.....	.....	Fine; trace ferrite ghosts	
	6Q	83.5	85.0	100.5	104.0	16.5	12.5	26.5	24.5	452.0	456.0	Very fine, pitted with holes	
	6QQ	70.0	....	92.0	.....	23.0	....	44.0	....	.....	.....	Very fine, pitted with holes	
C	7N	38.0	....	64.0	.....	35.5	....	52.5	....	.....	.....	Fine, uniform	
.22-.25	7Q	69.3	....	95.4	.....	18.3	....	39.2	....	.....	.....	Very fine, sorbitic, ferrite	
Ni	7QQ	57.8	....	79.0	.....	27.3	....	47.7	....	.....	.....	Very fine, all sorbitic	
....													

X = inner zone T = tangential Q = quenched and drawn
Y = outer zone N = normalized QQ = double quenched and drawn

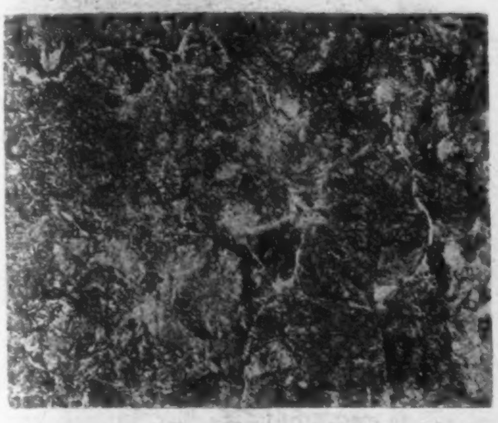
and drawing. Photomicrographs taken at a magnification of 50 diameters and some of them are shown and described in Figs. 11 to 26. Each casting was found to contain relatively large ferrite areas, locally decarburized areas, or long ferrite veins outlining very coarse primary crystals.

The most serious of the low carbon areas were found in castings Nos. 3*A* and 6, the latter being shown in Figs. 21 to 26. These areas are not completely eliminated by normalizing and persist even after quenching and drawing but have been almost completely eliminated by the double quench and draw treatment. The normalizing treatment, for the most part, greatly refines the structures while quenching and drawing produces a sorbitic structure with partially diffused ferrite. Structures after the double quench and draw compare favorably with those of large heat treated steel forgings.

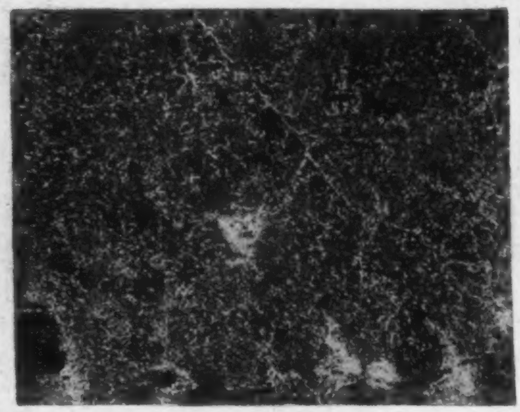
11



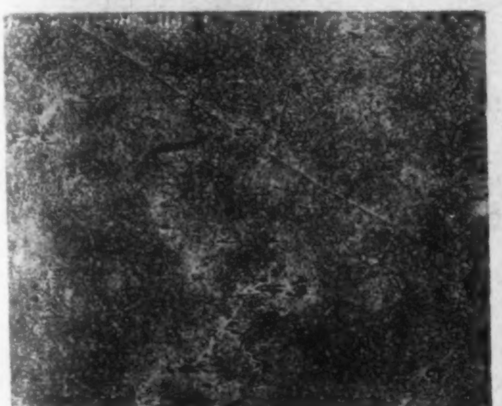
12



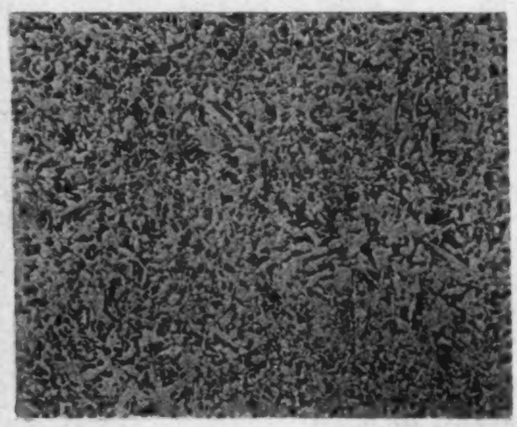
13



14

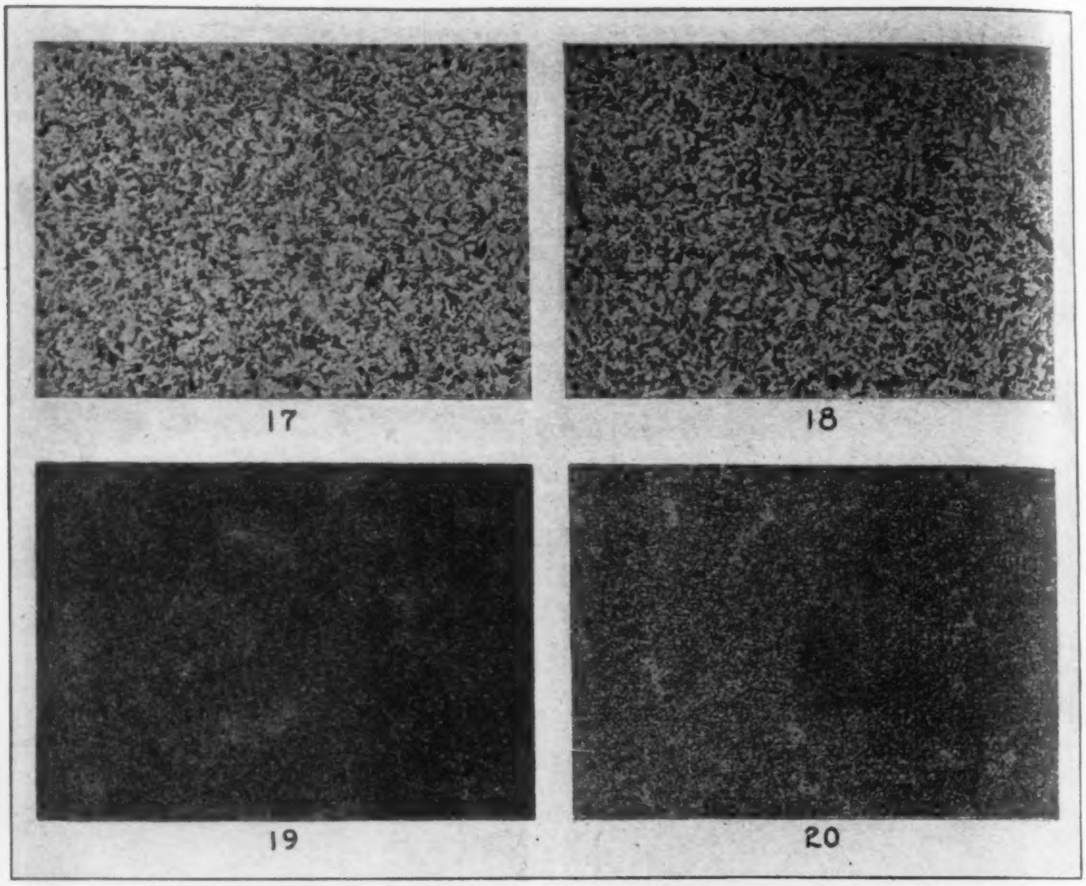


15



16

Picric acid etchings × 50. Fig. 11—Transverse section Casting No. 5 as cast. Very coarse grained, apparently not annealed. Average structure pearlite with thin polyhedral ferrite network. Is fairly uniform except ¼-inch zone adjacent to bore where large eutectoid areas about 10 points higher in carbon are visible. Fig. 12—Radial, longitudinal section of Casting No. 5 similar to Fig. 11. Fig. 13—Tangential section of Casting No. 5 with structure slightly finer than that of Figs. 11 and 12. Fig. 14—Casting No. 5 normalized showing refined grain but traces of ferrite areas containing slag inclusions remain. Ferrite network not entirely eliminated. Small blow holes visible. Fig. 15—Casting No. 5 oil quenched and drawn. Sorbitic structure with partially diffused ferrite. Small carbon areas with slag inclusions still prominent. Fig. 16—Transverse section Casting No. 7 as cast. Fine grained uniform ferrite-pearlite free from blow holes and segregation or slag. Well annealed.



Picric acid etchings × 50. Fig. 17—Radial section Casting No. 7 as cast. Structure similar to Fig. 16. Fig. 18—Tangential section Casting No. 7 as cast. Structure fine grained but has few areas containing needle-like ferrite particles indicating incomplete annealing. Fig. 19—Transverse section Casting No. 7 after single heat treatment. Very fine sorbitic structure with ferrite network and a few ferrite areas not fully broken up. Fig. 20—Transverse section Casting No. 7 after double heat treatment. Structure fine and sorbitic. Network broken up but many ferrite areas still remain.

Conclusion

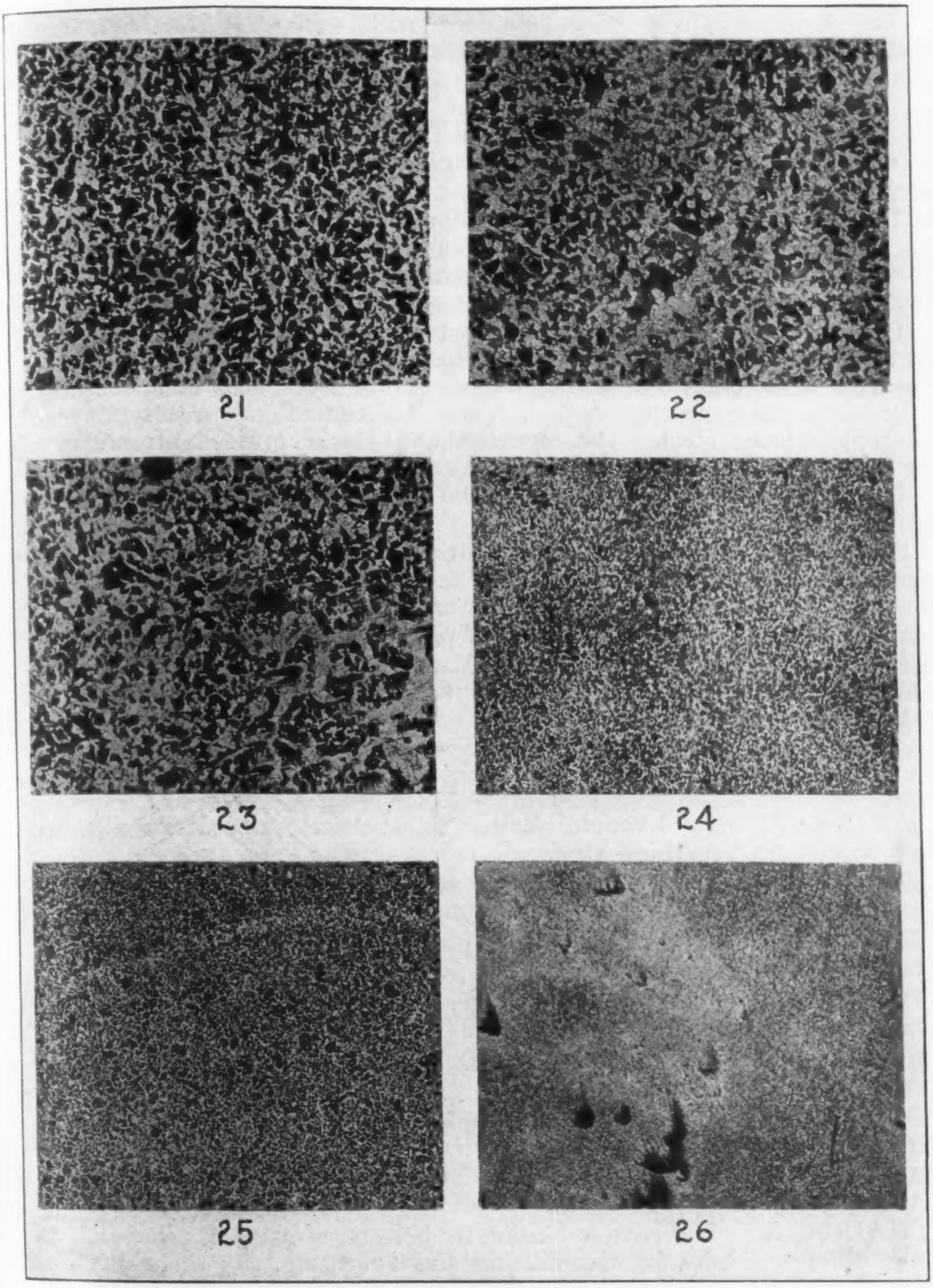
There were examined a miscellaneous lot of five castings in the form of cylinders of wall thickness ½ to 8½ inches made by the Millspaugh centrifugal process. Their composition ranged from two low carbon steels, with carbon 0.17 per cent and 0.23 per cent to three nickel steels averaging in carbon 0.33, 0.46 and 0.66 per cent and in nickel 2.69, 2.35 and 2.92 per cent respectively.

Segregation of the elements carbon, phosphorus, sulphur, nickel and copper appears to exist to a slight extent but only radially, and is most marked in a narrow zone about 1/16 inch depth next the inner surface. Manganese and silicon do not segregate in this type of casting. The greatest carbon segregation was 0.09 per cent in nickel steel of carbon 0.66 per cent and nickel 2.92 per cent and the least, 0.02 per cent in another nickel steel of carbon 0.33 per cent and nickel 2.69 per cent.

The brinell and scleroscope hardness practically follows the segregation.

The only evidence of unsoundness was the presence of small blowholes in the inner zone, usually within 1/16 inch of the surface.

The density across a section is practically constant, the variation being 0.004 in 7.836 grams per cubic centimeter.



Picric acid etchings × 50. Fig. 21—Transverse section Casting No. 6 as cast. Although not annealed has fine grain structure. Traces of fir-tree crystals found near inner edges and coarse primary crystals are outlined by thin ferrite network but no slaggy ferrite areas appear. Fig. 22—Radial section Casting No. 6 shows more pronounced fir-tree crystals than Fig. 21. Fig. 23—Tangential section Casting No. 6 shows a cluster of slaggy low carbon areas. Traces of fir-tree crystals found also. Fig. 24—Casting No. 6 normalized. A fairly uniform fine grain ferrite-pearlite structure has been produced. Fig. 25—Casting No. 6 water quenched and drawn. Sorbitic with fine network of undiffused ferrite. Slight traces of ferrite veins, partially broken up found. Fig. 26—Casting No. 6 double quenched and drawn. Although structure greatly refined and ferrite is well diffused, shadowing traces of ferrite veins remain. Area pitted with tiny holes shown.

The mechanical properties show, in general, somewhat greater strength, and elastic limit and resistance to shock but less ductility in tangential than in longitudinal direction.

The internal stresses developed in the castings by this centrifugal process of manufacture, as determined from measurements on three rings from each of two castings, show values of the order of the elastic limit with the outer zones in compression.

The effect of heat treatment in improving the physical properties of the castings is very marked. The results suggest that the properties of such castings suitably treated may rival those of forgings of the same chemical composition.

The microstructure of some, at least of these castings, is better than that of ordinary castings; certain ones show pronounced ingotism or dendritic structure. The nickel steels contain more slag inclusions than is usual in ordnance steel, showing that this centrifugal process may not clear up a basic steel. The ingotism and coarse grained structures of these centrifugal castings can, in general, only be removed by prolonged and repeated heat treatments, in other words normalizing followed by double quench and draw.

The above account is limited to a description of the tests, and no references are given as to the details of the manufacturing operations since the bureau had no first hand information concerning them.

Acknowledgements should be made to the members of the staff of the Divisions of Chemistry, Structural Materials, and Metallurgy who assisted in these tests and in particular to G. N. Nauss, who followed the tests through in detail.

DISCUSSION OF DR. BURGESS' PAPER

MR. BRAYTON: I should like to ask whether that centrifugally cast steel was under very high stress.

DR. BURGESS: It is under that stress due to the rotation. I can see no other cause for it except that it might be due to the actual freezing.

MR. BRAYTON: What would happen if you went to a much higher rotation? Would the metal crush?

DR. BURGESS: Theoretically, yes; practically it would not; you would probably rupture your apparatus first.

CHAIRMAN: I should like to ask Dr. Burgess what he means by normalizing?

DR. BURGESS: I suppose 120 people here could answer that question better than I can. It was our practice to heat the material up to a temperature depending on its chemical analysis, and to hold it from one to three hours depending on the size of the piece, and then air cool.

CHAIRMAN: The reason I asked is because we had a discussion as to the difference between normalizing and annealing. Is there any difference?

DR. BURGESS: I am not open for cross examination.

FIRST PRINCIPLES OF THE CARBONIZING PROCESS—A CONSIDERATION OF THE FUNDAMENTAL FACTS AND FACTORS

By Theodore G. Selleck*

That the art of carbonizing steel has not been reduced to an exact science, the well-informed steel treater is ready to admit; he is also ready to admit that there are strong arguments against the possibility of its ever being so developed that it will become a really scientific process; and yet the writer believes that the carburizing of steel, by the process of absorption, or, more technically speaking, the cementation process, may be followed with as much scientific accuracy as we find today in the application of any other process connected with the manufacture or treatment of that metal.

As long as manufacturers can not produce casehardening steel within narrower limits than present manufacturing specifications allow for the range of carbon and other chemical constituents of the metal, it can not be said that the manufacture of steel has been reduced to an exact science.

When those who carbonize, or otherwise, subject steel to thermal or thermochemical treatment are able to specify steel as "10 point" and get it 10 point instead of 10 to 20 point; or order "15 point" and get just that instead of 15 to 25 point; or when they order "20 point" they get what they order instead of 20 to 35 point, etc., both the manufacturer and the steel treater, and especially the carbonizer, may make some headway toward reducing their processes to an exact science.

The carbonizing process has no power to remove or to improve the imperfections, irregularities or other faults put into the steel during the process of manufacture; rather does it magnify or intensify them. If the variation of the carbon content is 10 points in the original steel it will be all of that in the carbonized product with an accompaniment of other variations of quality; if there is a wide variation in the content of other chemical constituents of the metal, they also will be reflected in the final results of carbonizing. It may not be by any increase of content of any element but carbon, but the uniform carbonizing and heat treatment of steel parts that vary in chemical analysis is sure to bring a corresponding variation in ultimate results.

As illustrating this the following tests, showing the effect of uniform treatment upon steels varying ten points, or more, in carbon content, are given. Analysis, before carbonizing was found to be:

	Carbon per cent	Silicon per cent	Sulphur per cent	Phosphorus per cent	Manganese per cent
Steel No. 1........	0.21	0.005	0.041	0.025	0.43
Steel No. 2........	0.11	0.005	0.034	0.010	0.45

Eight samples of each steel were subjected to identical carbonizing temperature and time and given the same subsequent heat treatments.

In the physical test every piece of the No. 2 steel, after carbonizing, showed up well for hardness, strength, and ductility after quenching at 1590 degrees Fahr. for the first quench, and 1425 degrees Fahr. for the second one. The pieces of No. 1 steel, when subjected to the same temperatures for quenching, were inferior in comparison; 25 per cent of them failed utterly because of brittleness, and none of the others were good enough to be considered usable.

*Consulting metallurgist, 4046 Jackson boulevard, Chicago. This is the first of a series of 10 articles on the "Carbonizing Process" written by Mr. Selleck.

The case of No. 2 showed a carbon content ranging from 0.90 to 0.97 per cent, while that of No. 1 ranged from 1.06 to 1.09 per cent. With the same carburizer, at the same time and under the same conditions, samples of another steel analyzing 0.24 per cent carbon, were carbonized and were given the same heat treatments as the above. They were, of course, a dead loss. The carbon content of the case on these samples ranged from 1.18 to 1.25 per cent.

That these samples, as well as the samples of No. 1 steel, might have proven satisfactory had the proper heat treatment been given them, is not doubted. The point to be considered is that if there is a range of 10 points in the steel parts before carbonizing there will be the same range after carbonizing and the same heat treatment will not do for the minimum and maximum of such a range. If we subject steel of 0.15-0.25 per cent carbon to what we are accustomed to call "an average normalizing temperature" of say 1550 degrees Fahr., we may have some of the parts perfectly treated so far as the "core" is concerned, and some of them may not show 50 per cent efficiency when subjected to physical tests.

The most common fault found with the carbonizing process is that it is unreliable; that a variety of results are obtained in a single operation; and that no part of the process is capable of standardization because of these faults. The tests mentioned above, at least partly explain the causes of these variations and indicate the truth of the claim made in opening paragraphs that the art of carbonizing can not be made a science until the art of manufacture has reached that stage. When the manufacturer can furnish for carbonizing a steel of a more definite analysis, within two points instead of 10 or 15, we may do something toward standardizing our process of carbonizing and reducing it to an exact science.

But until we understand in some measure what the carburizing process is, something about the nature of the action or reaction that occurs during the operation of the process we can not undertake intelligently its application. What, then, is the carbonizing process?

So far as present day knowledge of the phenomenon of carburization extends, the actual combination of carbon with iron by the cementation process seems not to be much more clearly and definitely known than it was at least three-quarters of a century ago. We are aware of its effects; we know by chemical analysis that the combination occurs, and by microscopical observation and physical tests we know of the structural changes produced in the metal because of such combination; but we do not fully understand the modus of the process of combination any more than we understand many other processes of the same natural laws that govern the process of carburization.

Our scientists and metallurgists have for many years been advancing various theories concerning the modus operandi of the carburization of iron, and if we follow their arguments and conclusions, we find ourselves lost in a theoretical fog; and our efforts to get to a sound practical basis of reasoning lead us around an endless circle.

For instance, in 1841, LePlay, a noted scientist of his day, advanced the theory of the carburization of steel, or "the diffusion of carbon into solid steel," as follows:

"The oxygen of the air, which surrounds the particles of wood charcoal, reacts with the carbon itself to form, first carbon dioxide (CO_2) then carbon monoxide (CO). The carbon monoxide would then yield to

the iron one-half of its carbon, again passing into carbon dioxide, and this would again be immediately reduced to carbon monoxide by the action of the carbon used as cement. In this way the cycles of reaction would continue indefinitely, and the carbon monoxide would act as a carrier, causing the penetration of the carbon into the solid metal."

While LePlay's theory is the one most generally accepted as correct, we find plenty of other metallurgists of his day and later, who dared to disagree with him, and put forth theories of their own in opposition to him; some of which may seem more comprehensible to the unlearned, practical operator of the process.

Marsden, another scientist, declared that the process of cementation was due entirely to the diffusion of the carbon, "in the form of an impalpable powder," into the steel "which, under the action of the high temperature was in an expanded and softened state"; while Ledebur declared that, "for the cementation of iron the intervention of gaseous carburizing compounds is in no wise necessary; * * * instead, the carbon can penetrate directly into the iron, and diffuse into it until it reaches a limit of saturation, depending upon the temperature."

Caron, another authority of the last century, said, "the compound which gives rise to the carburization of the iron can be none other than a volatile cyanide, capable of penetrating into the pores of the metal dilated by heat." He brought out a carburizing compound which has since been the basis of many of the modern commercial carburizers: Carbon, 3 parts; barium carbonate, 1 part." His theory of the action of this carburizer was that the barium carbonate, under high heat produced barium cyanide.

And so we find that many investigators of the phenomena of the carbonizing process, working for the most part along the same lines, have reached various conclusions concerning the actions and the reactions, that result in the carburization of iron through the application of the process of cementation.

The experiences and observations of the writer have resulted in a conviction that there is truth and merit in all the many theories, and that they are one and all but hints of the real truth concerning the process and its modus, that is not yet clearly understood.

Mannesmann, Marsden, and Ledebur, all practically agreed that the carburization of steel was accomplished through the molecular migration of solid carbon into the steel without the necessity of a gas being present, when the metal was highly expanded by heat.

Then LeChatelier came forward with the theory that "in the usual process of cementation nitrogen is the carrying agent of the carbon;" and we find that Fremy somewhat agreed with him in the declaration that "steel is, therefore, not a simple carbide, but a nitrogenized carburized iron." But, again, Professor Margueritte says regarding the subject of the nitro-carbide theory:

"The truth is that no one can prove today that steel is exclusively a nitro-carbide rather than a phospho-carbide, a chromo-carbide, a silico-carbide, a mangano-carbide, a titano-carbide, or a tungsto-carbide of iron." He took a sort of a middle ground, and declared that "iron combines with carbon, and is transformed into steel by contact * * * and also by the decomposition of carburetted gas; these two causes are present and act simultaneously in the cementation box."

And so far many years the controversy raged concerning the manner in which the carbon entered into the steel and there combined with the iron. The net result of all the investigation and discussion has been to establish LePlay's theory, practically as he stated it 80 years ago; but to the practical operator of the process, whose observations and practical experiences are his only technical training, a combination of all past theories more nearly fills the bill.

The most obvious result of all the above has been to prove beyond question the fact stated some centuries in advance of the authorities mentioned that: "when iron is packed in an earthen pot and surrounded with a mixture of old hoofs, horse dung, and pieces of hides, and is thoroughly sprinkled with the urine from a heifer, it will—after being baked for several hours at a good red heat—harden when quenched in water, equal to the best steel. To make it harder bake it longer."

In other words we have gained from it all a confirmation of the important fundamental fact that iron has such an affinity for carbon that it will absorb it from any carbonaceous matter with which it may be in contact when the physical condition of the two elements are in equilibrium.

It is a bit difficult for the uneducated operator of the process to understand that carbon can be dissolved in solid iron, when neither the iron nor the carbon are in a perfect fluid state; and the statement of Gullet that "the operation of cementation is really one of dissolving carbon in a solvent of iron" is not particularly enlightening to him when he knows that iron begins to dissolve or absorb carbon at 1472 degrees Fahr., according to Guillet, which is not sufficiently high to soften the metal enough for forging.

Roberts-Austen says "the diffusion of carbon into solid steel is a phenomenon entirely analogous to that of the diffusion of salt into water." But the the man, who has not studied the chemical phenomena of solid solutions, it seems a far cry from liquid water to solid steel.

Another analogy might be given that may be comprehended more easily. "The carbonizing of steel depends entirely upon the proper conditions being present when the steel is brought into contact with carbon; the principle of the process being based upon the well-known affinity the two elements have for each other. This affinity is limited only by their combining power, and the conditions of their contact." Here, then is the law under which the process operates—The Law of Affinities. We know very little about the law, in fact so little that some times we are in doubt about its existence; but it is hardly conceivable that rocks grow from pebbles; that pansies take on their myriad hues; that all that is beautiful as well as substantial in the material world about us is made so by the combinations of the various elements through their affinities for each other—that all this could be accomplished without the perfect working of a specific law governing every operation concerned in the development of these phenomena.

There is no difference between the processes involved in the absorption of water by a piece of dry wood and the absorption of carbon by iron. It is a question in both cases of the two materials being in the proper condition and in the proper relation to each other so that the laws governing their combination may operate.

To intelligently and successfully operate the carbonizing process it is essential that the operator should know how to establish the conditions

necessary for the accomplishment of the carburization of the metal according to the natural laws of absorption. These conditions being established, the process proceeds automatically, the results depending upon the period of time those conditions are maintained and the relation to each other of the following factors of the process.

There are four fundamental factors of the process, namely:

THE STEEL. Its nature and quality, as well as its physical condition. Steels of various chemical constitutions require varying thermal and thermochemical treatments. Steel when forged requires different treatment than when it is merely machined from the bar, and steel castings should have special treatment, according to their analysis and the service for which they are intended.

HEAT. The important factor of the process. It may well be termed the most important factor because upon the proper application of it depends the success of every operation. The metal can not absorb carbon until heat has established the proper condition in the iron; and the higher the temperature carried the more rapid will be the absorption of the carbon. Still there is a limit to the heating which must be observed if the best results are desired. Some steels require a higher temperature than others, but in all cases the velocity of penetration of carbon increases with the increase of temperature. These points will be discussed more fully later on.

CARBURIZER. It has been stated that iron will absorb carbon from carbonaceous matter of any sort if the proper conditions are established at the time of contact of the two. This is true, but iron has affinity also for other elements which exist in certain carbonaceous matter and which may be absorbed along with the carbon, thereby forming combinations not at all desired. Thus the carburizer should be chosen according to its freedom from all elements that might have a deleterious effect upon the steel.

TIME. This is the governing factor of the process. It bears a direct relation to temperature and is the gage of the operator for determining the depth of the penetration of carbon and, to some extent, the quality of the case.

The successful operation of the process depends upon the intelligence with which the operator is able to blend these four factors in his application of it.

Taking these four factors as a basis for the study of the process, we will consider them in the order named.

We must, first of all, understand the nature of the problem we have before us before we can intelligently begin its solution. If, for instance, we have a low carbon steel, approximately 0.15 per cent carbon, hot-rolled and simply machined from the bar, we have a different proposition to handle than we would have if we were called upon to treat the same carbon steel cold-rolled, or in the shape of forgings; and it will be advantageous to study the various conditions that the steel treater meets in a general case hardening business.

The steel generally used in parts that require case hardening is the type known as "S. A. E. 1020" and is of the following analysis:

Carbon	Manganese	Phosphorus (maximum)	Sulphur maximum)
per cent	per cent	per cent	per cent
0.15-0.25	0.30-0.60	0.045	0.05

The wide range of carbon permissible in this steel is at times the cause of irregularity of results, but it is undoubtedly the best all around type of steel for ordinary case hardened parts, where the demand is chiefly for a hard surface without much regard for strength. It is, however, in this type of steel that we find some of our hardest problems, because the same analysis is used for cold-rolled, and cold-drawn bars and tubes, that are frequently used in the manufacture of parts that require case hardening.

The difference in the action of the process upon hot-rolled steel and its action upon cold-rolled or cold-drawn steel, is that the velocity of penetration is much greater in the case of the hot-rolled, and there is a consequent difference in the chemical and physical condition of the case.

The Society of Automotive Engineers in specifying the carbonizing and heat treating temperatures for "1020" steel, makes no distinction between hot-rolled, cold-rolled, or cold-drawn steel, but every operator of the carbonizing process who is called upon to treat these various steels, all of the same analysis, knows there is a difference and often learn it to their sorrow and loss.

Because of the low temperatures at which cold-drawn, or cold-rolled steel gets its final passes at the mill, the structure of the surface is very dense and the temperature which would satisfactorily dilate a hot-rolled steel has very little effect upon the cold-rolled material. Even a higher temperature seems not to affect the velocity of penetration to the extent that would naturally be expected, and the only practical difference that can be suggested in the treatment specified by the S. A. E. seems to be additional time for the carbonizing period. This is not always a satisfactory solution of the trouble, as adding to the carbonizing time often has a bad effect upon the core.

The S. A. E. specified treatments for carbonizing "1020" steel are as follows:

"After forging or machining.

1. Carbonize at a temperature between 1600 and 1750 degrees Fahr. (1650-1700 degrees Fahr. desired.)
2. Cool slowly, or quench.
3. Reheat to 1450-1500 degrees Fahr. and quench."

This is "Treatment A" and is intended to be used where the development of a perfect core is not important. Where the conditions will permit, it is best to quench the parts direct from the pot as suggested, which will help somewhat in normalizing the core.

"Treatment B" is as follows:

1. Carbonize at a temperature between 1600 and 1750 degrees Fahr. (1650-1700 degrees Fahr. desired.)
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1550 to 1625 degrees Fahr.
4. Quench.
5. Reheat to 1400 to 1450 degrees Fahr.
6. Quench.
7. Draw in hot oil at a temperature which may vary from 300 to 450 degrees Fahr., depending upon the degree of hardness desired."

It is noticed that there is a wide range of conditions allowable in the heat treatment of this particular type of steel, but with all the liberal in-

structions given, one important part of the program of treatment has been omitted. The specifications indicate that these treatments should follow the forging or machining, of the parts. No forged parts should ever be carbonized until they have been carefully annealed, after forging and before machining. Many failures in case hardening may be traced directly to the practice of carbonizing parts that have not been properly annealed after forging. In all forgings there are always certain strains set up in the metal, which, unless relieved by annealing, are apt to produce failures of various kinds and some times of the most unusual and unexpected nature that prove hard to explain. Annealing of forged parts, before carbonizing, should never be neglected.

In the use of cold-rolled steel of the above type the "B" treatment should always be given the parts after carbonizing, but more about the heat treatment of carbonized parts will be given later on.

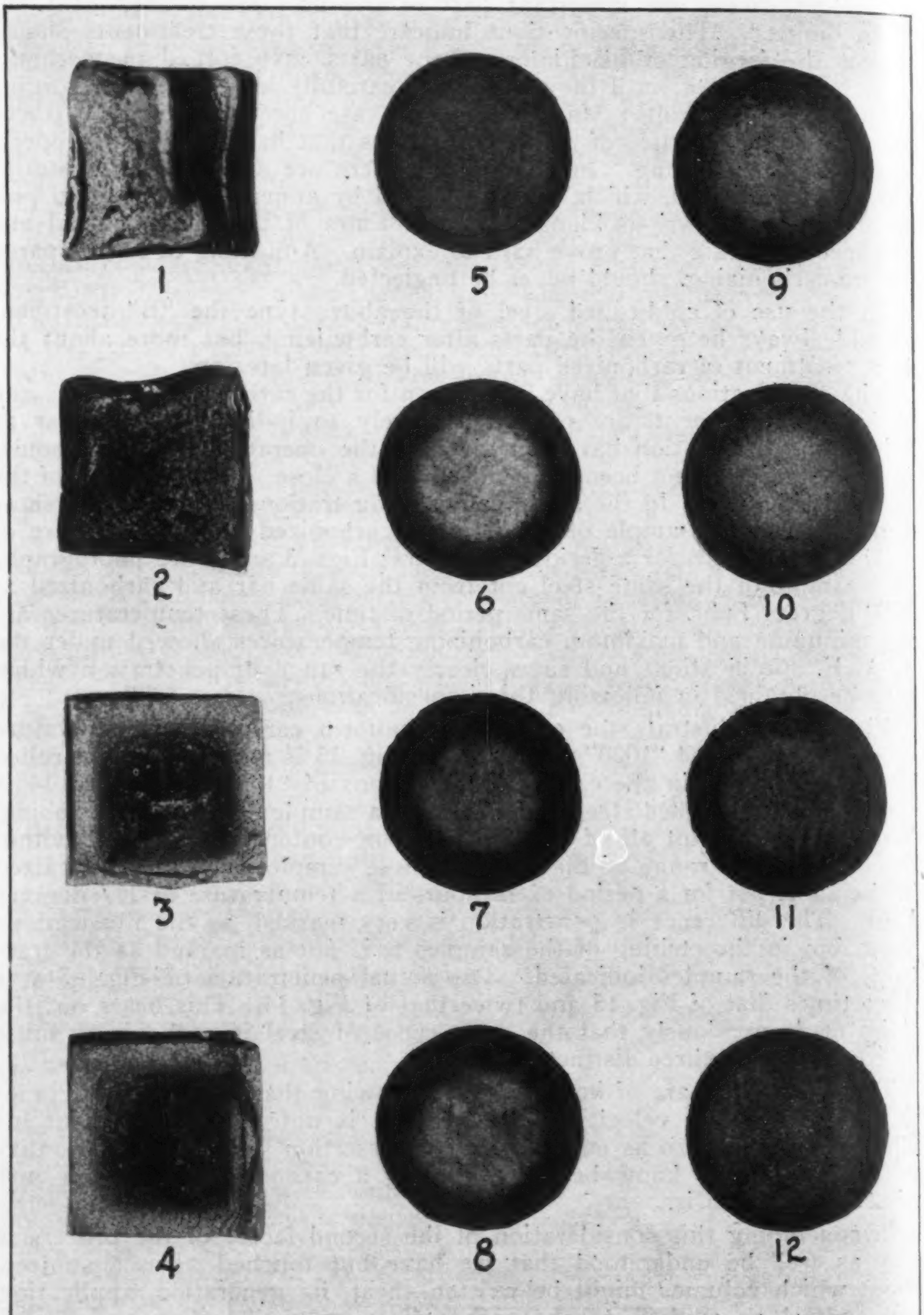
The specifications that have been given for the carbonizing of parts and their heat treatment, are presented merely to indicate that so far as scientific consideration has been given to the operation of the carbonizing process it has not been along the line of a close standardization of the thermal side of it. In the accompanying illustrations Figs. 1 and 2 show photographs of a sample of "1020" steel carbonized at a temperature of 1600 degrees Fahr. for a period of 6 hours; Figs. 3 and 4 are photographs of a sample of the same steel cut from the same bar and carbonized at 1750 degrees Fahr. for the same period of time. These temperatures are the minimum and maximum carbonizing temperatures allowed under the S. A. E. specifications and show clearly the range of penetration which may be obtained in following those specifications.

Figs. 13-15 illustrate the effect of a uniform carbonizing temperature upon three types of "1020" steel; that is Fig. 13 is a sample of hot-rolled steel, coming within the carbon specifications of "1020" steel, Fig. 14 is a sample of cold-rolled steel, and Fig. 15 is a sample of cold-drawn tubing. While these are not all of the same carbon content they are all within the wide carbon range of that steel. These samples were all carbonized in the same pot for a period of 12 hours at a temperature of 177 degrees Fahr. The difference in penetration is very marked, as the illustrations show, but in the etching of the samples it is not as marked as the fractures of the samples indicated. The actual penetration of Fig. 13 was three times that of Fig. 15 and twice that of Fig. 14. This bears out the claim made previously that the three types of steel in carbonizing must be considered as three distinct problems.

These examples are of importance as showing that heat, while it practically governs the velocity of penetration, is not the only element influencing it; and also as emphasizing the assertion previously made, that we should always know before beginning a carbonizing operation just what our problem is.

In concluding this consideration of the second factor of the process it may as well be understood that we have but touched upon a subject, about which volumes might be written—heat, its generation, application and control as applied to the carbonizing process—and more will be said upon the subject as we proceed with the discussion.

The third factor, the carburizer needs the most careful consideration because, as has been stated, from the carburizer it is possible for the iron to absorb elements that may be very injurious to the steel. For instance,



FIGS. 1 AND 2—SAMPLES OF "1020" STEEL AT 1600 DEGREES FAHR. FOR 6 HOURS. FIGS. 3 AND 4—SAMPLES OF THE SAME STEEL CARBONIZED AT 1750 DEGREES FAHR. FOR SAME LENGTH OF TIME. FIGS. 5 TO 12—THESE EXAMPLES ILLUSTRATE THE EFFECT OF VARIOUS CARBURIZERS ON STEEL UNDER UNIFORM CONDITIONS.

it would seem to be the height of folly to specify that sulphur should be kept very low in the original steel, below 0.05 per cent, and then surround it with a mixture of carburizing materials that would yield sufficient of that element to raise its content in the metal to a point that would make the steel useless. There are other elements that are equally pernicious in their effects which likewise may be found in impure carburizers, and so it is important that care be used in the choice of carburizing materials.

There are many angles to be considered in choosing carburizers. The manufacturers of them will inform the user that their particular carburizers are manufactured under formulas and processes that are scientifically correct and will perform the functions of the perfect carburizer under all conditions. But it is the opinion of the writer that no one carburizer will meet the requirements of all carburizing conditions, and that no one is so well able to know as the man who is called upon to use a carburizer under the conditions prevailing in his shop, which is the best for his particular purpose, providing, of course, that he knows enough about the process from experience to judge. It may be that a single type of carburizer may be successfully used on all kinds of work but the writer's experience has not given any proof of the fact.

The quality of work some times turned out by commercial case hardening plants, where but one grade of carburizer is used for all classes of work, is sufficient proof of the falsity of the claim that a carburizer that will do for parts that are very thin and do not require a carbon content above 0.80 to 0.85 per cent, will do also for parts that require a heavy penetration and a brinell hardness of 600 or higher.

When carburizers are so used, the hardness is usually governed by the subsequent heat treatment, which is a sort of an artificial method of producing something real.

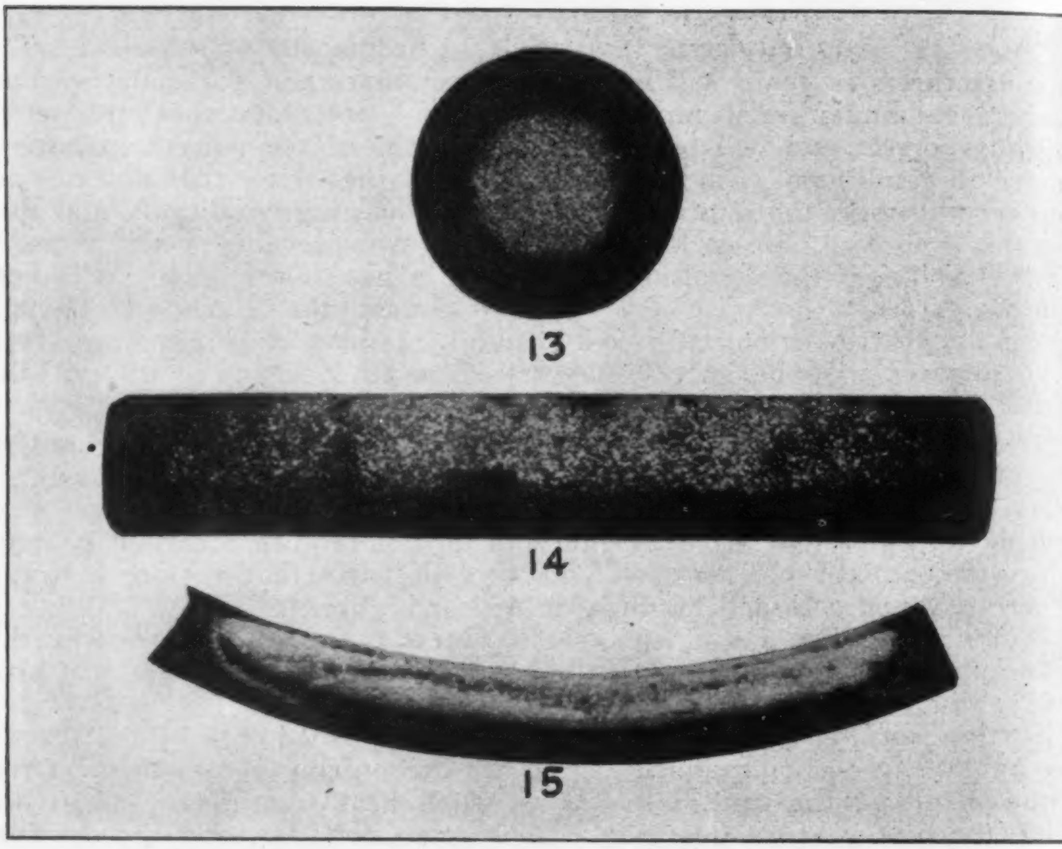
The highest grade of case hardening is accomplished only by the proper amount of carbon being added during the carbonizing period to meet the requirements of the case, followed by such heat treatment as will develop the best possible qualities of the carburized case, and the original steel in the core. In other words, it is better to have a case containing 0.80 per cent carbon and have it hardened at its maximum hardening temperature, than to have a case containing 0.90 per cent carbon and have it hardened at the minimum hardening temperature in order to have it meet the 0.80 per cent requirements. To harden steel at its maximum hardening temperature without passing its highest point of refinement, means to get the maximum efficiency in its wearing qualities; because, at that point the structure of the steel is at its best.

The function of the carburizer has been explained previously as being the source of the carbon with which the iron combines, either "through the decomposition of a carburetted gas" or through the molecular migration of carbon "in the form of an impalpable powder."

The consensus of modern opinion favors the former process as being responsible for the greater part of the action that results in carburization while the molecular progression theory is given but little credit, although there is much proof to be offered showing that it does play its part in all carbonizing operations.

But the gas theory being established, modern carburizers are compounded of materials that will produce the two gasses already mentioned, carbon monoxide and carbon dioxide and will set up and main-

tain those sequences of reactions mentioned by LePlay in his original thesis. The use of a pure carbon as a carburizer would be useless, because its action would be limited to the amount of oxygen contained in the small amount of air surrounding the carbon particles when it became heated to a carburizing temperature, since the evolution of monoxide is dependent first upon the evolution of dioxide. So in the manu-



FIGS. 13 TO 15—TYPICAL EFFECTS OF UNIFORM CARBONIZING TEMPERATURES UPON THREE TYPES OF "1020" STEEL. FIG. 13 IS A HOT-ROLLED STEEL BAR; FIG. 14, A COLD-ROLLED STEEL BAR; AND FIG. 15, A PIECE OF COLD-DRAWN TUBING. THE DIFFERENCE IN PENETRATION IS VERY PRONOUNCED.

facture of carburizers various materials are used in varying proportions as energizers or producers of carbon dioxide. It is the presence of these energizers that makes a carburizer quick or slow, according to their nature and their proportions in relation to the carbon base of the mixture. To an extent these energizers determine the carbon content of the case, and frequently they greatly influence the physical qualities of it, and for this reason the carburizer factor of the process should be the first to be standardized after the real standardization of case hardening steels has been accomplished.

How various carburizers affect steel under uniform conditions is shown by Figs. 5 to 12. At this time we can consider only what these photos show us of these samples—the difference in the depth of penetration, although there is much interesting data involved in the discussion of them, which will be taken up in a later paper. These samples were all carbonized in the same furnace at the same heat and for the same

period of time, but each sample was carbonized with a different carburizer.

Giolitti, in his *The Cementation of Iron and Steel,* says concerning carburizers "As for cementation proper, so for case hardening, the cements recommended by Reaumur, are fantastical mixtures of organic substances, such as the hoofs, hides, dung and urine of certain animals. But we have no right to be scandalized at this when we consider that many of the cementation mixtures still largely used today, and placed on the market under the strangest names are no less fanciful, nor do they give better results."

Of course Giolitti was speaking of conditions that obtained some years ago and our carburizer manufacturers have not been asleep; probably no branch of the manufacture of steel treaters supplies has had so much scientific study devoted to it as has the compounding of carburizers, especially during the period of the late war. Nevertheless it may be said that there are compounds on the market that are there chiefly bcause of their peculiar names, or because of claims that they are cheaper per cubic foot or per unit, or per something else and not because they are of any especially high quality, or merit.

Processes of manufacture are so hedged about by patents that the user of carburizers is compelled to choose between a limited number of compounds whether they are entirely satisfactory to him or not, unless he takes a chance and produces his own. By taking a chance is meant that unless proper mechanical equipment for mixing the various materials is used the mixture may not be uniform and unsatisfactory results follow its use.

Vegetable and animal carbons generally are used as carbon bases for carburizing compounds, with sometimes a small percentage of mineral carbon added; there are a few carburizers on the market, however, in which the carbon base is wholly mineral. Besides the carbon base a carburizer usually contains certain percentages of such energizing elements as barium carbonate, sodium carbonate, magnesium carbonate, calcium carbonate, and other carbonates and salts, which are usually proportioned according to the nature of the carbonaceous materials used in the carbon base, and the purpose for which the carburizer is to be used. Users of these materials have no way of judging their merit of efficiency except by actual tests made under standard conditions, which should always be done before a carburizer is adopted for regular use.

In many large plants, where metallurgical laboratories are maintained, tests are conducted and if the commercial carburizers available are not of the character best adapted to the work, the manufacturer is called upon to make a special mixture that will meet their requirements. This is done frequently, but only by the large users as it is unthinkable that every small user who thought he needed a special mixture could be accommodated. So it happens that the small user finds difficulty sometimes in getting just what he may need in the way of a carburizer, because he cannot go through a long line of tests of various mixtures, and there is no established standard of carburizers from which he can select one that will meet the demands of his particular work.

Carburizers should be compounded to produce certain definite results at certain temperatures upon steels of a definite analysis, and they may be so compounded. Where the demand for high class case hardening is

constant and steady, and the nature of the steel is known within close limits, the operator is not wise who does not fit his carburizer to his work, and if the manufacturer can not help him out, he is justified in working out his own material. The experiences of the writer with case hardeners, whose appreciation of the carburizer seems not to extend beyond the shape of its particles or its freedom from dust regardless of the other and more important qualities of it and who use one and the same carburizer for all manner of work under the most variable conditions, convinces him that this factor of the process needs more study, and its real nature and characteristics need to be better understood by the average operator of the process.

Economy must be considered, of course, in the selection of a carburizer, but that does not mean that the carburizer which contains the most cubic feet per ton is the most economical, even though its loss by use is less than those weighing much more per cubic foot; nor is it always the most economical carburizer that produces the greatest volume of carbon dioxide per pound of compound. The most economical carburizer is the one that meets every requirement of quality in the work it does without loss of parts because of more or less constant failures, at the minimum of cost for fuel, labor, wear and tear on equipment; and that will under these conditions show the lowest cost per cubic foot. The initial cost of the carburizer means nothing except as it is compared with its ultimate cost as indicated by the record of its performances in service.

The fourth factor of the process time is the gage of results. One of the very important parts of the process is the establishment of time schedules for the results desired. Time, bearing a definite relationship to temperature, it would seem not difficult to establish standard schedules if we knew just what that relationship was; but there is another factor to be considered—the carburizer.

We have seen that some carburizers act more rapidly than others at identical temperatures; that some produce high carbon cases while others produce lower carbon cases; so it is evident that the carburizer must be taken into consideration in the establishment of any schedule of time that we prepare. Herein we note again the weakness of the process because of the lack of any standardization of its factors; but, as a rule, the depth of case on ordinary case hardened parts is not important within several thousandths of an inch and, therefore, as long as there is sufficient depth to meet the requirements of the service to which the parts are to be subjected, a slight surplus usually is not any disadvantage. This does not apply to thin parts, or parts having light cross-sections; in such cases an excess of time in carburizing may entirely ruin the parts.

Someone, years ago, established a theory that "mild steel will absorb carbon at the rate of 1/16 inch in 8 hours, at a temperature of 1650 degrees Fahr.", but the same depth of penetration is often obtained in much less time, while in other cases a much slighter penetration is acquired in eight hours at that same temperature. While temperature and time bear a distinct relation to the depth of absorption of carbon, we have the nature of the steel to consider and the mechanical treatment it has received before being carbonized; only the use of good judgment on the part of the operator in applying time to his operations will insure satisfactory results. He must by observation learn the exact relation of time to temperature in the treatment of his own particular problems.

It is never advantageous nor economical to give a greater depth of case than the service of the parts will require; added depth means added time, and time is not only a measure of results but also a measure of cost. To all excess of time we must add excess fuel, excess labor, and excess wear and tear of equipment.

When we seek to apply the process, having attained some knowledge of the fundamental facts of its operation, our first problem is how to bring the four factors together into a working combination.

This is a large question; since again we have no standard equipment for this purpose but are obliged to follow methods of application that, from a scientific point of view, are very crude. They also are very ancient, for we still are in the "iron box age", although it is possible to obtain better containers than those made of cast iron. The difference is in the quality of the equipment rather than in any change in the methods of application. Alloy steels make a much better container than the old cast-iron ones, and from an economincal point of view they are in the end cheaper, but the initial cost is extremely high, and in many cases, prohibits their use.

Furnaces for carburizing are no different than those used for all other branches of steel treating, and choice of them rests upon their slight differences in mechanical construction.

In the use of such equipment as we have, there are a few rules that should be followed, carefully; for instance, in the use of containers of any sort the idea is not to use them as large as possible to conserve furnace space, or for any other reason. On the other hand they should be

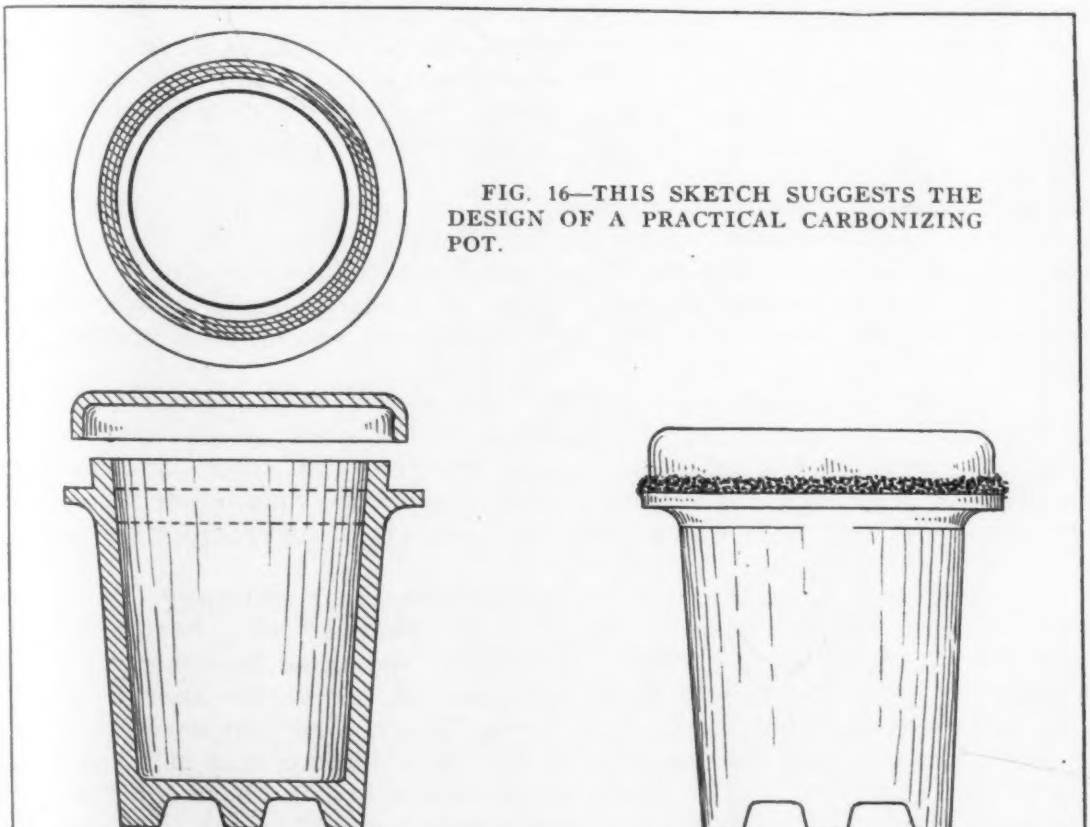


FIG. 16—THIS SKETCH SUGGESTS THE DESIGN OF A PRACTICAL CARBONIZING POT.

as small as possible and hold as few parts as economy will permit. It must be remembered that the heat, which is so important for the operation of the process, reaches the interior of the box or pot from the outside and must penetrate to the center of the box before there is uniformity of temperature in the steel parts. The time required for this transfusion of heat throughout the mass of material, depends largely upon the volume of steel in the pot. If it be too large or too compact, the travel of the heat toward the center will be so slow that uniformity of temperature may never be established; for if it is, the parts nearest the walls of the container will have had a carburizing temperature a much longer time than those in the center of the mass. From such practice results much of the irregularity of results. For this reason containers should be used that will give as rapid and as uniform heating throughout as it is possible to obtain.

All containers should be so designed that they can be tightly sealed; the covers should be made so that they will fit over the top and permit luting with fireclay below the top of the pot, so that the clay will not become mixed into the carburizer, as the presence of fire clay, scale from the boxes, and other foreign matter must be kept out of the carburizer if it is to be re-used. A suggestion for a practical carbonizing pot is shown in Fig. 16. Where the form of the parts will permit, round pots should be used, rather than square, or oblong, because in their use there is much less danger of placing the pots so close in the furnace that they will not heat uniformly. In placing the containers in the furnace sufficient space should always be allowed between them for the free circulation of the hot gases about them, and the round post facilitates such arrangement.

In designing pots or boxes for carbonizing it should be borne in mind than depth and length are not so objectionable in considering size, and capacity, as breadth is, thus a long narrow box will be more practical and satisfactory than a short wide one, where there is a chance for choice in the matter.

One other item of equipment must be considered and a very important one—the pyrometer. No case hardener should attempt the operation of the carbonizing process without the help of a reliable pyrometer, and if he is not experienced in the application of such instruments he should seek the help or advice of a competent pyrometer specialist in making his installation.

A pyrometer may be to an operator one of two things, a positive help in knowing the exact thermal conditions of his work at all times, or it may be a positive hindrance to him in knowing the exact conditions of his work at any time. It depends largely upon the manner of its installation and the care with which it is kept accurate in its readings by means of regular and accurate checking.

In selecting a pyrometer for the case hardening room ruggedness and simplicity should be considered as well as efficiency as a heat recorder. The pyrometer really is a simple instrument so far as its construction is concerned, since it has but three fundamental parts—the thermocouple, "the finger on the pulse"; the lead wires, "the nerves that carry the sensation of heat", and the recorder which in a human way acts as "the brain" of the system. The more simple these are in their construction the more practical they will be for the rough usage they are likely to get in the case hardening room.

When the pyrometer has been installed, if it be the best made, the most accurate and the most rugged, it is not to be considered as a substitute for the eternal vigilance of the men on the job.

Intelligence is the supreme factor of the carbonizing process and if it is lacking, all the other factors and the best equipment that can be secured will not produce satisfactory results.

These are a few of the fundamental factors of the process that should be known to the operator before he attempts its application, and are stated with the supposition that the process is to be applied to the treatment of such steels as are ordinarily used for case hardening. The treatment of other steels, such as alloy steels, will be considered in future articles, with a more intimate consideration of the factors.

It will not only be interesting but helpful for the operator to know how to judge the quality of his work from the observation of fractures, and also from microscopic examination, and micro-photographs, all of which will be included in our future study of the process.

INFORMATION DESIRED

One of the members of the Society submits a question for which he would appreciate suggestions from members who have had some experience with his difficulty. All answers submitted to the editor will be forwarded to the member very promptly.

"We have been experiencing difficulty in finding the proper material for plugging the center holes in tools before hardening in order to reduce cracking to a minimum. Different compounds tried out do not seem to stick in the holes and, therefore, I would welcome any suggestions as to good material to use for such work."

A CORRECTION

Through error the article entitled "A Discussion of Molybdenum Steels" appearing in the March issue of TRANSACTIONS was shown as written by Charles McKnight, president of the Carbon Steel Co., Pittsburgh. The author of this article was Charles McKnight Jr., works manager of the Carbon Steel Co.

NECESSARY PRECAUTIONS TO OBTAIN UNIFORMITY IN THE HEAT TREATMENT OF STEEL

By H. C. Loudenbeck*

(A Paper Presented by Title at Philadelphia Convention)

So much has been written regarding the heat treatment of steel that it seems futile to add to the literature on this subject unless the facts already accumulated can be presented in a new and original manner or new information can be obtained which will be useful to the art.

To obtain uniform results is one of the most difficult of the heat treater's problems, and to obtain these results certain precautions must be taken, which are often overlooked by the manufacturer. As a typical example, steel is purchased according to a specification that gives the desired physical properties when properly heat treated. The order is accepted by the steel mill and the steel manufactured and rolled accordingly. It is inspected by the purchaser's inspector who advises that it corresponds to the specification both chemically and physically and the shipment of the steel is authorized. After it is received by the purchaser and perhaps retested, and he is satisfied that the proper heat has been shipped, it is unloaded in the stock yard either in a pile by itself or unloaded on a pile supposed to be of the same specification.

It is afterward discovered that through some error in marking the steel, it has been mixed with a heat having a different composition. The whole lot, however, has been delivered to the forge shop and made into forgings which were delivered to the heat treating plant, the results of which are obvious: irregularity, rejections, and endless trouble by the user. This is only one of the many irregularities which may be found after the steel has been received by the purchaser. For example, the steel may not be properly labeled or tagged or the tags may become lost and uncertainty exists as to the particular quality of steel stored in the yard. Again, parts of bars from the forge shop are returned to the yard, stored with steel of different composition, afterward made into forgings, the supposition being that the lot of forgings are identical in composition.

From personal experience, the author is satisfied that great care should be used along these lines, especially as to the proper marking and storing of steel received in the forging yard. In these days, when so much attention is given to production and tonnage, the matter of quality often is overlooked and it requires constant supervision to see that the correct steel is used for the forgings intended.

If possible, each heat should be piled separately in the yard and correctly labeled with the heat number and specification number. When this particular lot is used for the forgings intended, this heat number should follow on the forging itself. If this requirement is too great for practical forging operations, heats of similar physical and chemical properties may be segregated and given a suitable code number representing the quality of steel. For example, a steel requiring 0.40 to 0.50 per cent carbon may be divided into two grades, namely, 0.40 to 0.45 per cent carbon and 0.46 to 0.50 per cent carbon. This will enable the forger to make less changes in marking dies and will also require fewer changes in heat treating.

*Engineer of Materials, Union Switch & Signal Co., Swissvale, Pa.

In a certain class of forgings it may be necessary to analyze each bar and grade accordingly. This has been found necessary for the manufacture of crankshafts for aircraft motors. In some cases, it may be necessary to make physical tests on each shaft from coupons attached thereto, the testing to be done before the shafts leave the heat treating department.

It has been found desirable to have someone connected with the metallurgical department in touch with the forging steel yard and supervise the marking and sampling of the steel as received from the mills. A man of this type is best qualified on account of his training and experience as he fully appreciates the importance of using a uniform steel of known composition in order to obtain uniform physical properties in the forgings made from that grade.

Another element which enters into the irregularity of heat treated forgings is the variation in the same heat of steel. For example, carbon and sulphur often vary considerably due to a segregated condition. Practically every heat varies more or less in this respect. Of course, this variation may be caused occasionally by mixed blooms of the mill but usually, it is due to segregation in the ingot which will cause a variation in the composition of the bars rolled from it. In other words, the blooms from the upper portion of the ingot will contain a higher percentage of carbon and sulphur than blooms from the lower portion of the ingot. It will be seen readily that bars rolled from these blooms will vary in proportion. A few examples on the variation of carbon in the same heat are illustrated as follows:

Size of Ingot Inches	Ingot No.	Heat No.	Carbon in Per cent Bottom of Ingot	Carbon in Per cent Top of Ingot
20 x 20	4	4323	0.46	0.48
	17		0.47	0.52
	4	6933	0.49	0.50
	12		0.46	0.50
	5	4325	0.53	0.63
	14		0.53	0.63
	3	6934	0.45	0.53
	1		0.45	0.51
	5	4333	0.54	0.61
	15		0.55	0.66
	3	4335	0.47	0.50
	10		0.44	0.51
	4	7437	0.44	0.48
	12		0.45	0.52

These are not exceptional heats. They were taken from the usual run of open-hearth practice. The ingots were cropped at the blooming mill until free of pipe as indicated by the shearing. This required from 20 to 35 per cent shearing. Samples were taken from the upper and lower bloom after the discard had been taken. It can be seen readily that bars rolled from the upper anl lower blooms would have practically the same composition as given above. The sulphur in these particular heats was quite low, running not over 0.035 per cent, usually in the neighborhood of 0.025 per cent and no great segregation was shown in this respect. It would be interesting to observe the effect of high sulphur, say 0.06 per cent in the ladle analysis in regard to segregation since many contend that sulphur running 0.06

per cent or slightly over does not have a detrimental effect on the physical properties of the steel. While this may be true, it should be considered that most specifications specify that the drilling should be taken half way between the center and outside of the bar. When this is done it does not represent the sulphur which may be in the center of the piece due to segregation.

Our experience has been that segregation is more liable to take place when the sulphur runs over 0.05 per cent than otherwise. It has been found that where the sampling is done according to the accepted method, a variation from 0.06 per cent, half way between the center and outside, to 0.12 per cent, when taken from the center of the bar, this steel will not make a desirable forging and will cause considerable irregularity during the heat treating process.

Irregularity in physical properties of forgings often is caused by variation in size and thickness of the forging at different portions and in some cases this is very difficult to control in order to have a uniform hardness throughout the piece. For example, an axle having a pad considerably thinner than the main body of the axle will refine and harden much stronger than the main portion. While this is overcome, to a certain extent, in the drawing operation, the final results will show considerable variation in the parts. It is difficult to overcome this and it often is necessary to draw the axle so that it will show a minimum hardness in the body in order to bring the hardness on the pad to the maximum. In other words, it means that a study must be made of the piece to be hardened before a definite program of hardening is accepted, thus it is a good plan to make tests on a few pieces.

By abnormal heats is meant heats of steel having the proper chemical composition but not having normal physical properties under regular heat treating. One particular heat which contained 0.36 per cent carbon and used for axle steel was difficult to refine with the ordinary process except in very small sections. Ordinarily no difficulty was found in hardening this steel to 250 brinell by quenching in cold water from a temperature of 1550 degrees Fahr. However, in this particular case the maximum hardness obtained was 185 brinnel. The analysis showed it to be normal with the exception that it contained more than traces of aluminum. The steel manufacturer may draw his own conclusion as to the finding of aluminum in steel but we cannot but think it had something to do with the difficulty in refining the steel.

In our experience, cold water should be used for quenching wherever possible as it has better penetration and gives more uniform results. It is often necessary to take certain precautions when water is used for quenching chrome nickel steel. The temperature of the water must be raised in some cases to about 110 to 120 degrees Fahr. and in the case of crankshafts, the time of quenching should be only a fraction of a minute, depending upon the size. After quenching they should be removed immediately to the drawing furnace. These precautions are necessary to prevent cracking.

The hardness of low carbon steels can be considerably raised by quenching in caustic soda solution. The strength of this solution should be 1 to 4. We have raised the hardness of a 0.20 per cent carbon steel from 185 to 300 brinell by means of this quenching medium. This was obtained on a section about 3 x 4 inches. It is necessary when using a solution of this sort to use a circulating system to keep the quenching medium cool.

Where oil is used it has been found that a grade of paraffine oil having a viscosity of 190 at 80 degrees Fahr. gives good results. This is improved by the addition of a small amount of fatty oil. The addition of 20 per cent refined whale oil gives excellent results.

This article is intended to throw out suggestions of a practical nature rather than a dissertation on the fine points of the art. Of course, it is understood that it is necessary to have the proper heat treating furnace, the proper temperature control, the proper time and manner of quenching, but unless the right grade of steel is provided for the purpose and steel of uniform quality, the results will be far from uniform.

THE RELATIVE ECONOMY OF ELECTRIC, OIL, GAS AND COAL-FIRED FURNACES

By T. F. Baily*

(A Paper Presented by Title at Philadelphia Convention)

Rapid elimination of natural gas as an industrial fuel and the rapid increase in the price of fuel oil, coupled with the statement of the United States Geological Survey that shortly it will not be available as an industrial heating medium, have brought the attention of the public generally to electric furnaces as one ultimate type of equipment that will combine not only accuracy of treatment to a degree which was never possible in fuel fired furnaces, but also reliability from the standpoint of supply of heat, as electricity has now become the most common of all commodities. It is true that there is a considerable thermal loss in the transformation of fuel to electric energy, nevertheless, the modern power plant is able to use the lowest grade of fuel; while the fuel used in industrial furnaces generally has been more expensive, as well as more difficult to obtain, as is evidenced by the gas and oil situation today.

From the standpoint of fuel conservation, is is of interest to note that even when taking into consideration the thermal efficiency of a modern power plant and distribution system of only 15 per cent, and an electric furnace efficiency of an average of 60 per cent, the net thermal efficiency for the entire cycle would be at least 9 per cent. On the other hand, assuming the same grade of fuel could be used conveniently in small industrial furnaces, which are now mostly fired by oil or gas, the efficiency probably would not run over 5 per cent, and probably it would require a higher grade of coal. Besides this, it would necessitate a modified design of furnace with a large combustion chamber. This would require a much larger floor space and would mean a complete new plant arrangement in most present installations. On the other hand, the electric furnace requires little more space than the present type of oil or gas-fired combustion furnace.

From a cost standpoint, it is difficult to make an accurate comparison, because of the wide variation in efficiency of the various fuel-fired furnaces; but taking as a basis, in the case of oil for heat treating operations, a consumption of 30 gallons of oil per ton of product, and with oil at 15c per gallon, which is the prevailing price at the present writing, the cost would be $4.50 per ton for fuel only.

With natural gas-fired furnaces, it is doubtful whether an efficiency of better than 6000 cubic feet of natural gas per ton of product can be maintained, and at a price of 50c per thousand cubic feet, the cost would be

*President, Electric Furnace Co., Alliance, O.

$3 per ton for fuel only. An electric furnace of the same capacity, which is taken as 1000 pounds per hour, would consume not to exceed 300 kilowatt hours per ton of material heated, with an average fuel cost of 1¼c per kilowatt, which would bring the cost to $3.75 per ton for fuel only.

Thus it is to be noted that under average conditions on small sized units, which are the most common types found in the heat treating industry, there is not a great variation in fuel cost; and, after all, this is of minor consideration when compared with accuracy of treatment, in which field the electric furnace is pre-eminently fitted to produce the highest quality of material. This is especially true of the electric furnace when coupled with automatic control devices, either of the time element or pyrometer control type.

In the larger capacity furnaces handling several tons per hour, direct coal-fired or producer gas fired furnaces, which obtaining their gas from soft coal, show much better economies; but in similar capacities, electric furnaces also show better economics. When taking into consideration the recuperative car-type furnace, the current consumption will fall when annealing of larger tonnages of steel, to as low as 120 kilowatt hours per ton. Thus with current at 1c per kilowatt hour, the probable rate under such conditions, would be $1.20 per ton for fuel, as compared with coal-fired furnaces with coal at $4.80 per ton. This would mean that from a fuel standpoint alone the producer gas fired-furnace would have to have a consumption of not to exceed 500 pounds of coal per ton of metal heated. Besides, the difficulty of obtaining the desired grade of coal to operate well in the producers; the additional labor cost for handling both fuel and ashes from the producer; and the much larger space required for both the producer and gas-fired furnace are additional disadvantages.

From a labor standpoint the electric furnace requires the least attention. In some of the larger units used in heat treating, consisting of two furnaces and an automatic quench between, two men on the combined unit will handle as much as three tons of material per hour; while in nonautomatic plain hearth-type fuel-fired furnaces several times as many men would be required.

Still more important, it would be impossible to control in this hearth-type fuel-fired furnace, the heating cycle and the quenching conditions of the heat treating operation with anything like the accuracy obtained by the automatic electric equipment. In some operations, such as the annealing of high carbon high chromium steel, wherein a definite cooling cycle is required, the electric furnace offers substantially the only certain means of controlling this cooling cycle.

The comparison of the three types of furnaces may be briefly summed up in the statement that while no great difference exists in the actual fuel cost between the three, the electric furnace at the present time is the one that seems most certain of a continued and uninterrupted supply of fuel. In numerous cases the actual fuel cost may be higher with the electric furnace than by oil or gas; but for the accuracy of treatment and from a standpoint of cost per ton of material which actually meets the specified requirements, the electric furnace probably will be cheaper than any of the other types, and can be depended upon absolutely from a production standpoint.

News of the Chapters

TEN WAYS FOR CHAPTER BETTERMENT

The American Society of Mechanical Engineers contributed the following as methods of improving the chapter, its activities, as well as the members, themselves. We believe it valuable to our organization and therefore are reproducing it:

1. ATTEND THE MEETINGS. By so doing, you can make a definite contribution to the support of your chapter.
2. TAKE AN ACTIVE PART IN EVERY MEETING. Contribute in good fellowship, and in intelligent discussion of papers.
3. GET TO KNOW YOUR FELLOW MEMBERS. This is always possible before the Meetings; there is a special Committee appointed for the purpose.
4. MAKE YOURSELF TO KNOW THE MEN YOU HAVE ELECTED TO OFFICE IN THE CHAPTER. If there is work that you are willing to help in, let them know it.
5. BE A WORKING MEMBER. If asked to serve on Committees do it, and do it well.
6. DO YOUR PART IN INCREASING THE NUMBER OF MEMBERS. Both in the Society and the Chapter. One new member per year for each present member means 100 per cent growth.
7. BE A BOOSTER! REALIZE WHAT A. S. S. T. STANDS FOR IN THE LARGE, and let this attitude of mind be reflected wherever and whenever possible.
8. BEAR THIS IN MIND: Your officers and committee chairmen will welcome constructive criticism.
9. REMEMBER THIS IS YOUR CHAPTER. Yours to build up, or yours through apathy to let stagnate. In your own case, be a builder up.
10. YOU'RE NOT ONLY A STEEL ENGINEER; YOURS ARE THE RESPONSIBILITIES OF GOOD CITIZENSHIP. A. S. S. T. stands for the best ideals of both. Through the A. S. S. T. are the means for promoting both.

WASHINGTON CHAPTER

The Washington chapter of the Society had a very interesting meeting on March 18 at the Bureau of Standards. The speaker of the evening was Dr. G. K. Burgess, chief of the division of metallurgy of the Bureau of Standards, who presented a paper on the "Properties of Metals at High Temperatures, and Their Relation to Heat Treatment".

At a meeting of the chapter called in the ballroom of the Harrington hotel, the chapter was reorganized by the appointment of a nominating committee who presented before the chapter the following list of nominations:

Chairman—S. Tour, Ordnance Department.
Vice Chairman—W. L. Blankenship, Navy Department.

Secretary-Treasurer—H. J. French, Bureau of Standards.
Chairman Finance Committee—P. E. McKinney, Navy Dept.
Chairman Meetings Committee—H. E. Handy, Washington Steel & Ord. Co.
Chairman Membership Committee—H. J. French, Bureau of Standards.

These officers were unanimously elected. The chairman of each of the above committees was empowered to appoint the remaining members of his committee. Mr. Handy, chairman of the Meetings Committee, appointed Mr. Strauss of the Navy Department, and J. S. Vannick of the

H. J. FRENCH
Secretary-Treasurer, Washington Chapter

Ordnance Department as the other members of his committee. The Executive Committee is to consist of the three officers and the chairman of the Finance and Meetings Committees together with two additional members. Accordingly, S. B. Hunnings, metallurgist of the Washington Steel & Ordnance Company, and Dr. G. K. Burgess, of the Bureau of Standards, were elected members of the Executive Committee.

SYRACUSE CHAPTER

About 125 attended the meeting of the Syracuse chapter on Feb. 24, held in the Technology Club rooms, when A. H. d'Arcambal, chief metallurgist of Pratt & Whitney Co., Hartford, Conn., presented a paper on "High Speed Steel, Its History, Manufacture and Heat Treatment." This was one of the best meetings the local chapter has had, due to the fact that the discussion was very lively and also to the fact that Mr. d'Arcambal was master of his subject. His entertaining personality assisted him materially in getting a splendid hearing for his paper.

A joint meeting of the Syracuse sections of the American Society for Steel Treating, and the American Chemical Society was held on Friday evening, March 4, at the Chamber of Commerce rooms. Over 200 members gathered to hear Dr. John A. Mathews, president of the Crucible Steel Company of America, Pittsburgh. Dr. Mathews spoke upon "Crucible Steel Products and Their Application", and paid particular attention to the advances made in the steel industries in the local mills.

DETROIT CHAPTER

The March meeting of the Detroit chapter was held on March 14 at the Board of Commerce rooms, and was addressed by A. D. Freydendahl, engineer of the Chicago Flexible Shaft Co., upon the subject of "Principles of Combustion as Applied to Industrial Furnaces." About 100 were in attendance at this meeting which proved to be one of the most successful the chapter has had.

ROCHESTER CHAPTER

About 50 attended an informal discussion on the "Hump Method of Heat Treating", at the Camera Works, on March 4. Many interesting points were brought up for discussion and the evening proved very instructive.

CHARLESTON CHAPTER

The March meeting of the Charleston chapter was held on March 1 at the Kanawha hotel, when D. M. Giltinan spoke on "The Metallurgy of High Speed Steel". Some 65 members were in attendance, and the paper which was well given, was heartily received. A general discussion followed, lasting more than hour.

HARTORD CHAPTER

The February meeting of the Hartford chapter was held in the Chamber of Commerce rooms on Feb. 24, when James A. Baldwin presented a paper on "Wrought Iron." A very good discussion followed the presentation of the paper.

The March meeting was held in the Chamber of Commerce rooms on March 10 and attended by about 65 members and guests. The main paper of the evening was presented by A. P. R. Wadlund, of the Henry Souther Engineering Co., on "The Bessemer Process." The subject of chromium was also discussed, and a paper presented on the "Nomenclature of Hardening Terms." The discussion was very interesting.

PHILADELPHIA CHAPTER

The Philadelphia chapter held its regular meeting on March 25 in the auditorium of the Engineers Club. W. L. Patterson, director of technical research, Bausch & Lomb Optical Co., presented an illustrated lecture on "The Optics of Metallography". The meeting was well attended and the discussion was lively and instructive.

TOLEDO CHAPTER

C. M. Brown, vice president of the Colonial Steel Co., Pittsburgh, spoke before the members of the Toledo chapter on "Standardization of Tool Steel". The meeting was held in the rooms of the Commerce Club on March 10. Previous to the meeting a dinner was served in Kests' restaurant. Mr. Brown has made a very careful study of the standardization of tool steel, and his paper was consequently of much interest to those in attendance.

PITTSBURGH CHAPTER

The March meeting of the Pittsburgh chapter was held March 15 at the Chatham hotel, and was addressed by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering,* who spoke on "What is New in Metallurgy". Mr. Thum handled his subject in a very able manner, speaking also of the lines upon which development in future might be expected.

MILWAUKEE CHAPTER

The Milwaukee chapter had a very interesting meeting at the Hotel Medford on Feb. 23 which was addressed by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering.* The meeting was attended by a large number, and was preceded by a dinner at the Hotel Medford.

SPRINGFIELD CHAPTER

The March meeting of the Springfield chapter was held on March 18 in the Chamber of Commerce building, when Hannibal A. Kunitz, engineer of the Advance Furnace & Engineering Co., presented a paper on "Automatic and Special Continuous Furnaces". Mr. Kunitz was well qualified to speak on this subject because of his wide experience with the design and construction of furnaces. The discussion following was one of the best that has been held for some time and was very lively and evidenced appreciation of the value of the talk.

NEW YORK CHAPTER

About 60 members were in attendance at a meeting of the New York chapter held at the Machinery Club. The lecture of the evening was by J. A. Brown, vice president of the W. S. Rockwell Co., on "Factors Governing Production of Heated Products". The meeting was preceded by a dinner at the Engineers Club.

CLEVELAND CHAPTER

One of the most enjoyable meetings the Cleveland chapter has held for some time was when they took advantage of the presence of a number of well known men who were in Cleveland to attend a meeting of the National Nominating Committee, on Friday, March 25. The Nominating Committee was invited to remain over, and furnish the basis of the program for the meeting, and they spoke on the following subjects:

J. Fletcher Harper, assistant superintendent, Allis Chalmers Mfg. Co., Milwaukee, Subject: "Effects of Deep Etching".

Major A. E. Bellis, metallurgist, U. S. Armory, Springfield, Mass. Subject: "Quenching of High Speed Steel".

A. W. F. Green, chief of laboratory, John Illingsworth Steel Co., Philadelphia Subject: "Things to Be Done".

C. U. Scott president, C. U. Scott Co., Rock Island, Ill. Subject: "Critical Points. Who Discovered Them? What are they?"

Quite a diversity of subjects was brought up for discussion, and it proved to be one of the most interesting meetings the chapter has ever held. The dinner was served at 6:30 and was well attended.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

AURELL, Carl (M-2), Billings & Spencer Co., Hartford, Conn.
BACKUS, Harold A. (M-3), care Gallaudel Aircraft Corp, E. Greenwich, R. I.
BARNES, Cyrus (M-1), 201 Devonshire St., Boston, Mass.
BEEARS, Byron (M-3), 401 "N" St., Reading, Pa.
BIHL, Wm. (M-3), Iron Mountain Co., 927 W. 95th St., Chicago, Ill.
BORNSTEIN, Hyman (M-12), 636 10th St., Moline, Ill.
BRAYTON, H. M. (M-2), Frankford Arsenal, Philadelphia, Pa.
CARABIN, M. A., (Sb-1) Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
CARUTHERS, M. W. (M-3), 439 Franklin Ave., Wilkinsburg, Pa.
COLBUS, H. H. (M-2), Halcomb Steel Co., 633 Arch St., Philadelphia, Pa.
COOPER, Ransom (M-3), Sanderson Wks., Crucible Steel Co. of Amer., Syracuse, N. Y.
DAVIS, G. F. (M-3), 2 Hubbard Court, Charleston, W. Va.
DENISON, Winthrop W., (M-3) 300 Walnut Place, Syracuse, N. Y.
DRISCOLL, J. J., (M-3) Sanderson Wks., Crucible Steel Co. of A., Syracuse, N. Y.
DUFFY, G. F. (M-1), 76 Lawrence St., Waltham, Mass.
EDGETT, H. J. (M-1), 52 Greenwood Ave., Greenwood, Mass.
EXNER, W. F. (M-12), Manche Storage Battery Co., 190 Kingshighway, St. Louis, Mo.
FAY, H. H. (M-12), 523 S. Columbia St., South Bend, Ind.
FULTON, L. M. (M-3), 3208 Carroll Ave., Chicago, Ill.
GAMBLE, D. E. (M-3), 6341 Ingleside Ave., Chicago, Ill.
GIBSON, L. H. (M-1), 3 Fordham St., Jamaica Plain, Mass.
HEATH, Leslie C. (M-1), Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
HIGGINS, J. J. (M-1), 12 Fern St., Pittsfield, Mass.
HOLSBERG, W. A. (A-12), 112 Clybourn St., Milwaukee, Wis.
JACOBSON, Theodore (M-3), S. K. F. Ball Bearing Co., Hartford, Conn.
JARDINE, James J. (M-3), care Y. M. C. A., Syracuse, N. Y.
JENKINS, Geo. W. (M-1), 1413 W. York St., Philadelphia, Pa.
JOHNSON, James A (M-3), 1445 Baker, Detroit, Mich.
JOSEPH, Carl F. (M-1), 4845 Concord, Detroit, Mich.
KING, B. F., Frost Gear & Forge Co., Jackson, Mich.
KONOLD, Geo. F. (M-3), Warren Tool & Forge Co., Warren, Ohio.
KOONZ, John F. (M-1), 3306 "H" St., Philadelphia, Pa.
LARDNER, James K. Jr. (M-9), 723 20th St., Rock Island, Ill.
LIZOU, Leo (M-12), 1372 Richard St., Milwaukee, Wis.
MAAGE, A. E. (M-12), 718 34th St., Milwaukee, Wis.
MAHONEY, J. D. (M-1), 58 Hamilton St., Dorchester, Mass.
MATHEWS, J. R. (A-3), 205 Kresge Bldg., Detroit, Mich.
MATTISON, H. H. (M-3), Sanderson Wks., Crucible Steel Co. of Amer., Syracuse, N. Y.
MILLER, Chas. H. (M-1), McIntosh & Seymour, Auburn, N. Y.
MOORE, C. D. (A-3), 1331 St. Clair Ave., Cleveland, O.
MORLEY, L. Morton, (M-11), care Brown Instrument Co., Wayne Junction, Philadelphia, Pa.
NEWKIRK, E. D. (M-3), Onondaga Steel Co., Syracuse, N. Y.

NEWSTROM, J. V. (M-3), Iron Mountain Co., 927 W. 95th St., Chicago, Ill.
NIEHAUS, A. D. (A-1), care Crucible Steel Co., 1518 N. 9th St., St. Louis, Mo.
PARKER, Heber (M-12), Studebaker Corporation, South Bend, Ind.
PENHOLE, W. S. (M-3), 1509 Washington St., Charleston, W. Va.
PFEIFER, Carl B. (A-3), 1723 Lafayette Blvd., Detroit, Mich.
POTTS, Chas. W. (S-3), care Horace T. Potts & Co., Philadelphia, Pa.
REED, B. F. (A-12), 684 Cramer St., Milwaukee, Wis.
RICKABAUGH H. H. (M-11), 809 Eighth Ave., Altoona, Pa.
RIDER, Fred H. (M-2), 112 N. Cedar St., Massillon, Ohio.
ROWE, Chas. O. (M-1), care Electric Alloy Steel Co., 511 Penn. Bldg., Philadelphia, Pa.
SAYRE, Mortimer F. (M-12), Union College, Schenectady, N. Y.
SEIDELL, Arthur J. (M-12), St. Louis Paper Case & Tube Co., 4400 Union Ave., St. Louis, Mo.
SHERMAN, P. B. Jr. (M-1), 2108 E. 96th St., Cleveland, O.
SHERWOOD, R. A. (M-3), Halcomb Steel Co., Syracuse, N. Y.
SMITH, Robt. F. (A-3), 413 Seitz Bldg., Syracuse, N. Y.
SMITHIES, M. W. (M-3), care Atlas Ball Co., 4th & Glenwood St., Philadelphia, Pa.
SQUIRE, Thos. S. (M-12) 144 Lascellus St., Syracuse, N. Y.
STARY, Lawrence G. (J-2), 3159 E. 90th St., Cleveland, O.
STOECKLE, Chas. H. (M-12), 2114 N. 19th St., Philadelphia, Pa.
SYKES, W. P. (M-1), 1770 E. 45th St., Cleveland, O.
THOMAS, C. H. (M-3), 499 Ridgewood Ave., Glen Ellyn, Ill.
THUR, Jos. H. (M-1), 3329 N. 18th St., Philadelphia, Pa.
WEST, Hubbell B. (M-3), Halcomb Steel Co., Syracuse, N. Y.
WHONNHART, Lewis, (M-3) Sanderson Works, Crucible Steel Co. of America. Syracuse, N. Y.
YOUNG, Harry M. (M-1), Western Wire Products Co., 3rd & Spruce St., St. Louis, Mo.
ZIMMERLI, F. P. (M-1), Solvay Process Co., Detroit, Mich.

CHANGES OF ADDRESS

ACKERMAN, A. H.—from 2230 Leland Ave., Chicago, Ill., to 427 Reaper Building, 105 N. Clark Street, Chicago, Ill.
ARTHUR, Alec C.—from 1845 Jones Street, Indianapolis, Ind., to 1916 Jones Street, Indianapolis, Ind.
BAKER, F. C.—from Wilson Maeulin Co., 306 Monroe Bldg., Chicago, Ill., to 163 W. Washington St., Chicago, Ill.
BEEMAN, E. P.—from 137 Beals Ave., Detroit, Mich., to 475 Baltimore, West, Detroit, Mich.
BEGG, Thomas K.—from Wm. E. Baulieu, Bridgeport Brass Co., Bridgeport, Conn., to Thomas K. Begg, Bridgeport Brass Co., Bridgeport, Conn.
BIRMINGHAM, T. F.—from 1160 Morraine Street, East Chicago, Ind., to 1160 Morraine Street, Hammond, Ind.
BLACK, J. W.—from 159 Oak Grove Ave., Springfield, Mass., to 28 Dayton St., New Haven, Conn.
BOOTH, E. C.—from 2342 Park Ave., Indianapolis, Ind., to 223 W. 5th St., Peru, Ind.
BROWN, N. E.—from U. S. Electrical Mfg. Co., 300 S. Central Ave., Los Angeles, Cal., to Box 155, Los Angeles, Cal.

BURK, Edward J.—from 1210 Sturm St., Indianapolis, Ind., to 333 Walcott St., Indianapolis, Ind.

COPELAND, Alexander W.—from Det. Gear & Machine Co., 127 Franklin St., Detroit, Mich., to 670 E. Woodbridge St., Detroit, Mich.

COPELAND, C. W.—from Locomobile Co., Bridgeport, Conn., to Timken Roller Bearing Co., Detroit, Mich.

CRESSMAN, H. E.—from E. F. Houghton & Co., 511 Gwylm Building, Cincinnati, Ohio, to 131 W. Woodbridge Street, Detroit, Mich.

CROWE, Victor—from 620 Central Ave., Dunkirk, N. Y., to 19 Chant St., Fredonia, N. Y.

DALE, F. M.—from Rochester Steel Treat Co., 108 Platt St., Rochester, N. Y., to Rochester Steel Treat. Co., 15 Caledonia Ave., Rochester, N. Y.

DALGAARD, Aeil—from Camillus, New York, to 60 Marcellus St., Camillus, New York.

DAUNCEY, Wm. Geo.—from 50 Park Ave., Montreal, Can., to Cascade Inn., Shawinigan Falls, P. Q., Can.

DAVIS, Frank G.—from 302 East Woodbridge St., Detroit, Mich., to 1437 Franklin St., East, Detroit, Mich.

DORCHESTER, Paul—from Surface Comb Co., 366 Gerard Ave., Bronx, New York City, to 173 Sylvan Ave., Leonia, New Jersey.

DOWIE, H. E.—from Ward Tool & Forging Co., Latrobe, Pa., to 439 Ohio Ave., Wilson, Pa.

DRAKE, Frank B.—from care Johnson Gear Co., 735 Folsom St., San Francisco, Cal., to 8th & Parker, Berkeley, Cal.

EDWARDS, Wm. A.—from Ludlum Steel Co., 33 Woodward Ave., Detroit, Mich., to 1776 W. Lafayette Boulevard, Detroit, Mich.

ENGLEHART, R. J.—from 182 Mansfield St., New Haven, Conn., to P. O. Box 148, Yale Station, New Haven, Conn.

EVANS, H. J.—from 201 Western Ave., Aspinwall, Pa., to New Kensington, Pa.

FAIRFIELD, J. A.—from 1650 Lincoln Ave., Lakewood, Ohio, to care Eaton Electric Furnace Co., Taunton, Mass.

FAY, H. H.—from 502 S. Franklin Ave., South Bend, Ind., to 523 S. Columbia St., South Bend, Ind.

FOSTER, O. A.—from 811 Lakewood Ave., Detroit Ave., Detroit, Mich., to 133 Ferris St., Detroit, Mich.

FULLMORE, H. W.—from 1574 Quarrier Ct., South Charleston, W. Va., to 23 Curry Street, South Charleston, W. Va.

GOSSETT, E. J.—from care Bell & Gossett, 609 W. 30th St., Chicago, Ill., to 117 N. Dearborn St., Chicago, Ill.

GOWING, W. A.—from 30 Adelaide St., Detroit, Mich., to 66 Adelaide St., Detroit, Mich.

GRAY, R. T.—from 38 S. Dearborn St., Chicago, Ill., to 616 S. Michigan Ave., Chicago, Ill.

GREINER, R. C.—from U. S. Tractor & Machy. Co., Menasha, Wis., to 3411 Grand Ave., Minneapolis, Minn.

GUISWITE, R. D.—from 1533 N. Alabama St., Indianapolis, Ind., to 418 15th Apt. 42, Indianapolis, Ind.

HANDY, James O.—from Pittsburgh Testing Lab., 906 Bedford Ave., Pittsburgh, Pa., to Pittsburgh Testing Lab., P. O. Box 1115, Pittsburgh, Pa.

HEDIN, Oscar C.—from 412 S. 6th St., Minneapolis, Minn., to No. 100 First St., N. Minneapolis, Minn.

HILL, Jas. B.—from 303 Peoples Bank, Moline, Ill., to 512 Peoples Bank Bldg., Moline, Ill.

HITTLE, J. A.—from 1141 Laurel St., Indianapolis, Ind., to 4119 Broadway, Indianapolis, Ind.

HOLLANDER, J. A.—from 545 Enright Ave., Cincinnati, Ohio, to 2159 Lawn Ave., Norwood Station, Cincinnati, Ohio.

HOLLERITH, C. B.—from 2063 N. Meridian St., Indianapolis, Ind., to 3515 N. Penn Apt., Indianapolis, Ind.

HULBERT, L. G.—from care Mercer Motors Co., Trenton, N. J., to Hare's Motors, Inc., Bridgeport, Conn.

HUMPHREYVILLE, L.—from 1666 E. 32nd St., Cleveland, Ohio, to 480 E. 112th St., Cleveland, Ohio.

IRONSIDE SON & CO. (J. W. ROSE)—from 40 Muncing Lane, E. C. 3, London, England, to 39 Grosvenoi Place, London, England, S. W. I.

JACKSON, G. H.—from care National Steel Co., 111 W. Washington St., Chicago, Ill., to 2240 Washington Ave., Racine, Wis.

JOHNSON, Walter—from 301 Kentucky Ave., Indianapolis, Ind., to Singleton & Belt Ry., Indianapolis, Ind.

KELLOGG, W. O.—from General Combustion Co., 308 E. 42nd St., New York City, to 39 Cortlandt St., Suite 1013, New York City.

KLEIBER, Paul—from 60 N. Bolton St., Indianapolis, Ind., to 316 N. State St., Indianapolis, Ind.

KRETZSCHMAR, A. W.—from 142 Chene St., Detroit, Mich., to 600 Chase St., Detroit, Mich.

LANZ, Clarence—from 216 Irving St., Toledo, Ohio, to 2611 Albion St., Toledo, O.

LEARMOUTH, W. J.—from 268 Dexter Blvd., Detroit, Mich., to 8340 Dexter Blvd., Detroit, Mich.

LEVIN, Joseph—from 16 Margery Rd., Welland, Ont., Can., to 1933 Forbes St., Pittsburgh, Pa.

LILLY, Geo. C.—from 606 W. Market St., Bethlehem, Pa., to 707 W. Market St., Bethlehem, Pa.

MARLOWE, J. S.—from 204 Lombard Bldg., Indianapolis, Ind., to 536 Bankers Trust Bldg., Indianapolis, Ind.

MATHEWS, John A.—from Crucible Steel Co. of Amer., Pittsburgh, Pa., to 17 E. 42nd St., New York City, care P. O. Box 11, Grand Central Sta.

MILNOV, Edw. L.—from Ludlum Steel Co., Real Estate Trust Bldg., Philadelphia, Pa., to Ludlum Steel Co., Watervliet, N. Y.

MULL, H. C.—from 1540 McCormick Bldg., Chicago, Ill., to 122 S. Michigan Ave., Chicago, Ill.

NIGHTINGALE, G. V.—from Wilson Maeulin Co., 104 S. Michigan Ave., Chicago, Ill., to 163 W. Washington St., Chicago, Ill.

NISBET, Geo. B.—from Brier Hill Steel Co., Youngstown, Ohio, to Erie Smelting & Iron Co., Erie, Pa.

McINTYRE, F. J.—from 131 Center St., Jackson, Mich., to G. D. Bay City, Mich.

McKEAN, H. C.—from 1405 E. 89th St., Cleveland, Ohio, to 12440 Cedar Rd., Suite 4, Cleveland, Ohio.

OLCOAT, Frank—from 53 Cottage Place, New Britain, Conn., to 125 Smalley St., New Britain, Conn.

ORNE, C. O.—from Page Needle Co., Springfield, Mass., to 76 Hudson St., Somerville, Mass.

PIERCE, E. J.—from Columbia Graphophone Mfg. Co., Bridgeport, Conn., to Lewis Eng. Co., 25 Church St., New York City.

PLOURD, Wm. H.—from Simonds Mfg. Co., Brookfield, Ill., to 2911 Park Ave., Chicago, Ill.

PORTERFIELD, C. D.—from 29 W. 31st St., New York City, to 287 Willard Ave., West New Brighton, N. Y.

ROBERTS, E. H.—from John Obenderger Forge Co., Milwaukee, Wis., to 3209 Wells St., Milwaukee, Wis.

ROBINSON, J. W.—from Park Chem. Co., 29 Lovett St., Detroit, Mich., to 1305 Seventh St., Port Huron, Mich.

ROCK, Frank W.—from 166 Bunnell St., Bridgeport, Conn., to 43 Plymouth Court, Milford, Conn.

ROSEN, Joe—from care Linograph Co., Davenport, Iowa, to Rock Island, Ill.

RUNECKOFF, L.—from 2741 28th Ave. S., Minneapolis, Minn., to East Rt. No. 1, Box 26, Minneapolis, Minn.

SCHEUING, Fred—from 311 W. 26th St., New York City, to 2328 Richmond Terrace, Port Richmond, Staten Island, N. Y.

SCHRAMM, Otto—from 339 Bryant Ave., Syracuse, N. Y., to Homeside Steel Treating Co., Fourth St., Detroit, Mich.

SCHRIEBER, F. C.—from 1433 Sherwin Ave., Chicago, Ill., to 1433 Sherwin Ave., Evanston, Ill.

STACKS, D. H.—from Whitney Mfg. Co., Hartford, Conn., to 1558 Boulevard, West Hartford, Conn.

STANTON, R. F. V.—from 42 Collins St., Hartford, Conn., to 282 Laurel St., Hartford, Conn.

TERRY, T. B.—from 15 West First St., Dayton, Ohio, to 19 Richmond St., Dayton, Ohio.

WADLUND, A. P. R.—from 108 Prospect Ave., Hartford, Conn., to 319 New Park Ave., Hartford, Conn.

VANTASSEL, W. N.—from 275 Cooke St., Waterbury, Conn., to 206 Plaza Ave., Waterbury, Conn.

WEBB, G. A.—from 52 Ravenwood Ave., Detroit, Mich., to 105 Manistique Ave., Detroit, Mich.

WELCH, S. N.—from P. O. Box 1318, Providence, R. I., to 23 Sabine St., Providence, R. I.

WILLIAMS, J. H. G.—from Henry Souther Engr. Co. 11 Laurel St., Hartford, Conn., to care Billings & Spencer, Hartford, Conn.

WILLIAMS, R. H.—from care Messrs. Sidney Williams & Co., Sydney, N. S. W., Australia, to Constitution Rd., Dulwich Hill, Sydney, Aust.

ZILKY, Louis C.—from R. F. D., South Bend, Ind., to 626 E. Haney St., South Bend, Ind.

MAIL RETURNED

Any member knowing the present address of those listed under "Mail Returned" will confer a favor on the Society by sending the correct address to 4600 Prospect Ave., Cleveland, Ohio.

BARRE, Louis, Route 2, Gilletts Lake, Jackson, Mich.
HARING, Arthur W., 214 Newbury St., Boston Mass.
HARTLEY, E. S., 340 S. Pacific Ave., Pittsburgh, Pa.
KIEFER, A. E., 650 Beaconsfield, Detroit, Mich.
POWELL Geo. R., 605 Munsey Bldg., Baltimore, Md.
SUBBERRA, A. W., 625 Hamilton Ave., Detroit, Mich.
THOMPSON, P. E., Steel Sales Co., Jefferson & Adams St., Chicago, Ill.
WEIDNER, Robt., 217 S. Flower St., Los Angeles Cal.

Commercial Items of Interest

"Form Value of Energy in Relation to Its Production, Transportation and Application," a paper prepared by Chester C. Gilbert, consulting engineer, Arthur D. Little, Inc., Washington, and Joseph E. Pogue, industrial economist and engineer, Sinclair Consolidated Oil Corp., New York, and presented before the fuels section, annual meeting of the American Society of Mechanical Engineers, New York, Dec. 7-10, 1920, has been reproduced in bulletin form by the W. S. Rockwell Co., 50 Church street, New York. This paper discusses some fundamental factors governing the utilization of fuel resources. Two charts are included in the bulletin.

In the January-February, 1921 issue of *Metal Heating,* a journal devoted to the interests of heat treaters and forgers and published by the Tate-Jones & Co., Inc., Pittsburgh, are reprinted three articles recently published in TRANSACTIONS. The articles and their authors are as follows: "Steel for Machine Parts," by Robert M. Taylor, works engineer, the American Tool Works Co., Cincinnati; "Microconstituents in One Section of a Metcalf Test Bar," by Oscar E. Harder, associate professor of metallurgy, University of Minnesota; and "Heat Treatment of Automobile Springs," by Harry E. Hemstreet, general foreman, Sheldon Spring & Axle Co., Wilkes-Barre, Pa. The fourth article appearing in the publication is entitled "The Rotary or Rotating Hearth Furnace" and describes a furnace manufactured by the Tate-Jones & Co.

Land has been purchased by Horace T. Potts & Co., Philadelphia, containing about 10 acres at the corner of D street and East Erie avenue. This land, it is stated by the company, will be used as a site for a modern plant building later. It is estimated the investment will involve $500,000.

The American Gas Furnace Co. has concentrated its entire personnel at its main office at Elizabeth, N. J., where its two plants are located. It has discontinued selling through its former sole agents, E. P. Reichhelm & Co., Inc. These changes are part of a plan to place the entire organization of the company, more fully at the disposal of its customers.

To provide additional working capital for the development of its spring business, the capital stock of the Garden City Spring Works, 2300 Archer avenue, Chicago, recently was increased to $500,000. The company has become the sole licensees under the Dilley patents for the manufacture of self-oiling springs for the replacement trade, and it anticipates a large business in this line.

The W. N. Best Furnace & Burner Corp, New York, has been incorporated with $1,000,000 capital stock, by M. Roger, R. J. Sykes and W. H. Gillen, 1246 Pacific street.

A 40-page booklet in its third edition has been published by the Refractories Manufacturers' Association, containing the names and address of all the manufacturers of refractories in the country. This booklet also lists alphabetically all the various brands of fire brick and other refractories made by respective manufacturers. Copies can be obtained without cost upon application to Secretary Frederick W. Donahoe, 840 Oliver building, Pittsburgh.

A 20-page booklet recently published by the Steel City Testing Laboratory, Pittsburgh, describes and illustrates the hydraulic testing machines built by that laboratory. A feature of the pamphlet is the description and cross sectional diagram of a hydraulic rending and testing machine. The last few pages are devoted to Brinell testing machines and their operation, two hardness tables of diameter and depth of 10-millimeter steel balls being included.

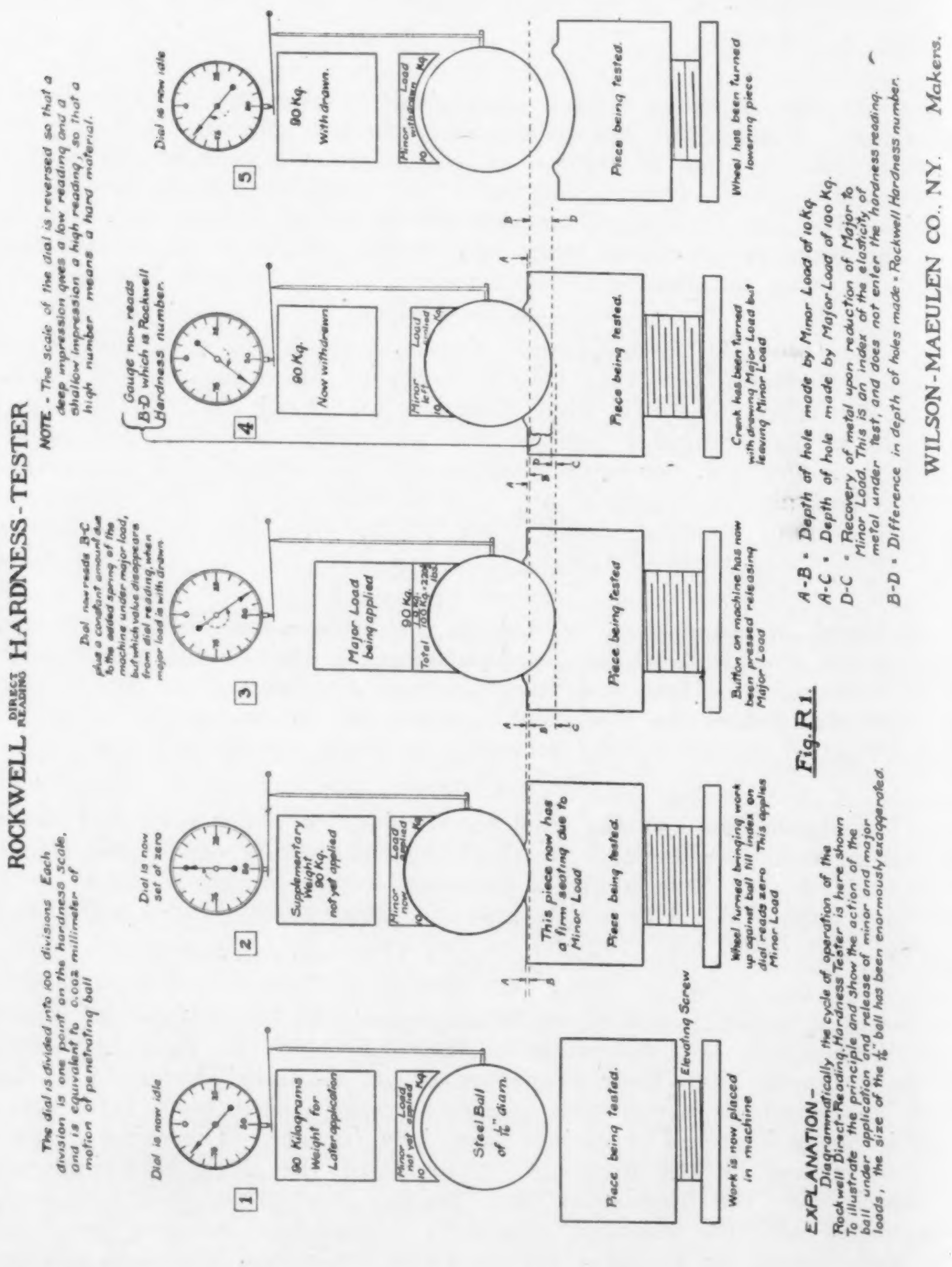
Packard Freight Transportation Digest, Vol. 3, No. 14, published by the Packard Motor Car Co., Detroit, contains an article entitled "Looking Inside Truck Steel To Find Economy and Long Life." This article discusses in plain language various heat treatments to which steel is subjected to secure the necessary requirements for service. A number of sketches and photomicrographs are used as illustrations. The purpose of the article is to acquaint motor truck buyers with the careful attention given the stressed parts of trucks.

"Control in Annealing," by George P. Mills, sales engineer, Electric Construction Co., Philadelphia, was published in the February publication of the Association of Iron and Steel Electrical Engineers. This paper, which was presented before the Philadelphia section of the association, shows the close setting of control devices necessary to secure the desired results.

"The Application of Gas Fuel to Forging," a paper presented before the American Gas Association by the industrial heating department, Henry L. Doherty & Co., New York, is published in the March 17 issue of the *Iron Age,* page 703. This article gives the requirements for a satisfactory forging furnace fuel and compares oil with coal.

Scientific paper No. 408, published recently by the Bureau of Standards, Washington, is a discussion of the "Effect of the Rate of Cooling on the Magnetic and Other Properties of an Annealed Eutectoid Carbon Steel." Eutectoid carbon steel specimens were cooled from 800 degrees Cent. in air in lime and at various rates in a furnace. The effect of these rates of cooling on the magnetic properties of the steel, most important of which are the maximum and residual induction, coercive force, permeability, and the magnetic reluctivity relationship and also the resistivity and scleroscope hardness are shown in tables and discussed. Microphotographs are used as illustrations. The paper shows that the change in structure from an essentially sorbitic one to "divorced" pearlite causes a gradual shifting of the bend in the reluctivity line and a greater difference between the values of the real and apparent saturation intensities.

A small portable direct reading hardness tester recently has been developed by the Wilson-Maeulen Co., 379 Concord avenue, New York. This machine operates upon the principle of employing in succession, a very light load, followed by a heavy load, an automatic indicator showing



the difference in depth between the impressions made by the two loads. In the accompanying illustration is shown and explained the various cycles of operation of the new tester.

(Continued on Page 42, Advertising Section)

been
York.
on, a
owing

WILSON-MAEULEN CO., NY. *Makers.*

oads.
rious